United States
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Forest

General
Technical
Report
WO-18

Proceedings of the Workshop in Visibility Values

Fort Collins, Colorado
January 28-February 1, 1979

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Service**

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August 1979

Proceedings of the Workshop in Visibility Values

Fort Collins, Colorado
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Preface

Planning for a workshop on the Values of Visibility began shortly after the passage of the Clean Air Act Amendments of 1977. Actually our interest originally developed when we first learned of Section 169A--the visibility provision. Our initial thoughts were that Congress or EPA would have a very difficult time setting any standards in an area where no criteria considerations existed. We also felt that indications of aerosol loadings due to identifiable sources and calculation of the resulting reduction in visual range, contrast transmittance, and red to blue color ratio were sufficient only to characterize the issue. The concept of a value would somehow need to be developed at some point because realistically, our system operates on the basis of cost/benefit logic.

We considered that a first step toward the end of establishing values for visibility was to gather a group of researchers and others involved with visibility in a workshop where each could present his or her ideas and interact with others considering the subject. We set out to develop a group who could identify the current state of knowledge in values (dollar and nondollar) of nonmarket commodities such as esthetics, wilderness, and a clear, unpolluted vista. We also wanted to be sure this group would be able to focus on issues associated with the Clean Air Act as well as the complex questions of atmospheric aerosol generation, behavior and effects, so we invited EPA and federal land management agency representation as well as atmospheric aerosol scientists. Funding was provided for the workshop as well as for development of these proceedings by the Park Service and Bureau of Land Management in the Department of Interior and from both operational and research components of the Forest Service.

In order to prepare people for the workshop we developed the bibliography which appears in the proceedings and was distributed along with a few facts and thoughts of ours on the subject. The workshop was initiated with a field trip to Rocky Mountain National Park and culminated with a final day of open discussions in both structured and unstructured formats.

FIELD TRIP

The field trip was designed to allow all participants a first-hand opportunity to view a Class I air quality area, and in particular, to view it after having seen a heavily air polluted urban area. Unfortunately the weather did not cooperate. Snow did not permit us to view the magnificent scenery of the Rocky Mountains. We were not able to experience Denver's brown cloud and a quick look at some visibility instrumentation was not of much interest in a driving snow storm at -10° C.

The hospitality provided us, however, in the Park's visitor center was not diminished by the harsh environmental conditions. At the center, Superintendent Chester Brooks, Deputy Superintendent Jim Godbolt, and their staff discussed aspects of park management and the air resource. Mr. Brooks pointed out that park and wilderness managers are making decisions every day affecting the preservation of these areas for the next 100, indeed, 1000 years. The challenges he remarked are related to the fact that we may be loving our parks to death in tremendous impacts from use and overuse of these areas. Mr. Brooks mentioned that visibility is being impaired on occasion by incursions of Denver smog into the park. The challenges of managing an area which is both close by a major urban complex and also represents a remarkable and unique resource to the country provided a good introduction to the later deliberations of the workshop. Jim Godbolt provided some interesting statistics on the use of the Park--about 3 million people visit yearly. That is, by the way, equal to the population of Colorado. He explained that the park had adopted a public transportation system to help alleviate congestion, parking, and other problems in particularly popular locations within the park. In discussing an old homestead which has been preserved and restored within the park, Godbolt made the point that more and more land managers must be attuned to the social context of their activities. Land management by the federal government must consider and provide a product which answers the social needs of our community. In some cases it was implied providing for these social needs is at conflict with the original protect and preserve Park Service responsibility. One example of this conflict is the use of fire as a wildland management

tool. In the ecosystems present in Rocky Mountain National Park, fire is a prevalent and necessary force. The park has established a wilderness fire policy to allow a level of fire in locations where it will benefit the ecology without causing any threat to private property or people. Last summer the park was cited by Boulder County health officials because of air pollution caused by smoke generated by such a fire which had unexpectedly gotten out of control. The point raised here is that land management may at times be in some conflict with some considerations of the Clean Air Act. Under these circumstances, it is important to balance the relative positive and negative factors of environmental and societal implications of activities and regulations.

Austin Condon, Forest Service District Ranger for the Estes Park District of the Arapaho-Roosevelt National Forest, the area which surrounds the National Park, explained the differences between National Park and National Forest management. The National Forests are operated under a multiple use concept wherein resources are used in a balanced fashion to provide a continuous supply of economic and social values to the American people. Indeed, in doing this the Forest Service often impacts generally what has come to be known as the visual resource. Now, the visual resource management responsibility is related to what people look at, rather than what they look through. However, Condon continued, there are many activities which the Forest Service conducts which affect both what we look at and what we look through. He further explained that, as a land manager, he had some considerable experience with the latter component of this problem. Indeed, the Forest Service has a well developed Landscape Management series which is a multiple volume set of directives which discuss managers sensitivities to visual resources, how to develop resource objectives, and then specifically how to maintain these objectives in activities we conduct. Condon concluded by reiterating that the urban environment was indeed encroaching on this provision of visual quality and he welcomed our workshop as a means of helping to clarify societal values and land manager's responsibilities in this distressing fact.

Following these presentations there was considerable discussion on the various points which were raised. Just what can a federal land manager do to protect his area from the encroachment of inferior air from an urban area? Nearly everyone wanted an opportunity to answer this one. A lot of ideas were discussed regarding, mainly, just how comprehensive and how specific the charge given to federal land managers in the Clean Air Act is. At the least the responsibility for protection of visibility is clear, although it awaits EPA's development of regulations. On the more extreme end is an "environmentalist's" interpretation of the affirmative responsibility to protect air quality related values, which includes utilization of the full responsibilities of the manager in order to protect these values.

This discussion provided, we thought, an excellent introduction to the specific areas the workshop was to address. The day was concluded with a pleasant meal and the talk presented by Dr. Myron Corrin, which is included in the proceedings.

We thank the authors of the papers in this proceedings for their enthusiasm and cooperation. The authors of contributed as well as invited papers submitted camera-ready manuscripts to expedite publication of these proceedings. Each contributor is responsible for the accuracy and style of his or her paper. Statements of contributors from outside the Department may not necessarily reflect the policy of the U.S. Department of Agriculture.

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This proceedings includes 17 papers which were presented at the Workshop. The papers consider various aspects of the problem of establishing values of clean air visibility in support of the national goal of visibility protection established by the Clean Air Act Amendment of 1977. They are organized into six sections including an overview, statements of advocates, management perspectives, physical and psychophysical considerations, behavioral and social perspectives, and economic perspectives. In addition, brief summaries of participants' discussions are included. A selected bibliography of over 210 papers dealing with valuing visibility is included.

Keynote Address:

The EPA Entropy Generator[1]

Myron L. Corrin[2]

Colorado State University

Introduction by Douglas Fox

It is a pleasure for me to introduce our speaker, Dr. Myron Corrin. Dr. Corrin is a professor of atmospheric sciences at Colorado State University with a PhD in physical chemistry from the University of Chicago. He worked at General Electric research labs and at the University of Arizona before coming to Colorado State University 11 years ago. Dr. Corrin's field of research is in surface physical chemistry and he is interested in aerosols and air pollution. Dr. Corrin has also been appointed by the Governor to the Colorado Air Pollution Control Commission, which is a regulatory agency for the state. The Commission works with the Air Control Division, a state agency charged with implementing the Clean Air Act. Dr. Corrin will be relating some of his experiences as a member of the Air Pollution Control Commission in his talk entitled: The EPA Entropy Generator.

Usually a talk of this sort can start either of two ways - you can take the academic approach and define your terms, or you can take the casual approach and tell a story. I think I prefer the first, so let me make some definitions. The Environmental Protection Agency is a governmental agency. It is a federal agency, established under mandate of Congress. The EPA has quite a number of functions. It serves as a regulatory agency, writes regulations, writes air quality standards, and writes emission standards. The agency also enforces these standards by proper action of the federal courts. Note that the EPA acts both as a legislator and police department. It is almost as if you let a police department write the laws. If you remember, this was one of the basic criticisms of the old Atomic Energy Commission, and I think this dual role will haunt the EPA in the distant future. EPA has other functions, which include funding research and providing funding directly to the states. This latter function is a very powerful weapon, since if the state does not behave, it may find some difficulty negotiating funding support. I am not talking about research support, but enforcement and staffing support. The next definition is entropy. This is a thermodynamic term. It really measures, if you will, the state of mixed-upness of something, down at the molecular level. The more a thing is mixed up and the more randomly it is arranged, the greater its entropy. The more perfectly ordered a system is, the lower its entropy. It is characteristic of entropy that it also measures that part of the energy of a system which cannot be used for useful work. I would therefore define an entropy generator as a device which effectively converts energy into entropy and thereby decreases the potential ability of the generator to perform anything useful. Incidentally, entropy plays a very important role in communication theory and also in information theory. It can be used as a parameter to judge the effectiveness of communication. The more effective communication, the lower the entropy associated with that communication.

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[1]Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

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If we look at EPA, we find a central headquarters located in Washington and we find a mass of centers containing a great many scientists located in North Carolina. I think you will find, generally, a fairly high quality of staff both at the national level in EPA, and at the regional level. However, at the higher level of the staffing, and I speak specifically of the regional director, there is no question in anybody's mind that politics play a very important role. And the choice of a director is made largely in terms of political affiliation rather than environmental qualifications.

I would now like to comment on some of the practical implications, at the state level of the organization and nature of EPA. The Environmental Protection Agency is charged with interpreting the statutes as written by the federal government. The statutes generally require such interpretations as well as formulating regulations based upon interpretations. Such interpretations have become particularly a matter of concern. If you remember rightly, all the states as of 1972 were required to supply a State-Implementation Plan (SIP). Colorado submitted such a plan. It happened to be rejected, and no objection was raised. Everything just kept rumbling along the same old way. The 1977 act, however, imposed sanctions for failure to submit an acceptable SIP, which frightened a lot of people since there was federal money involved. These monies were for programs like highways and sewage treatment facilities. In addition, there was a ban on the construction of any potentially large new emission source, which would strangle growth in most states. All of this caused a great deal of concern. So we knew in August or September of 1977 that the state would have to file a plan. The responsibility for filing such a plan in Colorado fell upon the Air Pollution Control Commission. The law very clearly mandates that where mobile sources (like the automobile) were concerned, local government would play a major role in writing the SIP plan. I think this provision for requiring local government participation was very wise, as I do not think local governments would accept a plan written by EPA nor would they accept a plan written by the state that involved controlling local traffic. They would accept, I think, the control of emission standards. They would accept inspection maintenance designed to insure that automobiles are maintained properly, but I doubt that local government would accept a ban on automobiles, a parking management plan, or any of the other alternatives which were suggested. Such alternatives would really affect life style. Congress was very wise in writing into the act the pronounced involvement of local government. The trouble with EPA was that although the law provided funds to local government to obtain the information which was necessary and to evaluate the control strategies they might want to adopt, the funds were never appropriated. The only assistance available at the technical level to the local community were the services of an EPA contractor. At least, this was our experience in Colorado. The delays in getting information from such a contractor were unbelievable. We, for example, did not get the input from this contractor with respect to the condition of air quality until September 1978, 1 full year after the plan was noticed and only 4 months before the completed plan was due in the EPA office. We never did get, in Fort Collins, an evaluation of control strategy. It is this type of breakdown in communication which contributes to what I am calling entropy. Let me show you how the thing works another way. The contractor promised us this information no later than July 1st, but nothing was forthcoming by July 1st. I moved before the commission that we instruct the Air Pollution Control Division to communicate with the EPA and suggest to them if that information were not forthcoming by the end of July, we would recommend canceling the contract and not pay the fees. That resolution was passed and sent to the Division who never wrote the letter.

Let me give you some other problems that we have experienced. We have been complaining to the State of Colorado for the last 5 years about the TSP standards. It is our contention that these standards simply cannot be met in the West with its climate that includes strong winds. These are standards, as you know, based upon mass per unit volume. Furthermore, if you delve back into the origin of these standards, you would find that most of the health work originates in England, and that the studies in England were correlated with an entirely different type of measurement. Furthermore, the studies were always conducted at a fairly high level of sulfur dioxide. In other words, I am concerned whether these standards really measure an impact on health or an impact on visibility. EPA, under the original Clean Air Act in 1970, was asked to evaluate these standards as additional information. This was never done. How many of you read the newspapers last Friday when the new ozone standard was announced? There was an extremely interesting comment by a member of an environmental group. Something like this is a day of infancy. This is the first time any standard was raised. And yet, as new information comes in, it is almost certain that some standards will be raised and other standards will be reduced, because the original standards, really, were nothing more than educated guesses, as is apparent if you go back and look at the criteria titles and see the data upon which these standards were promulgated.

We have another problem, and this is really not the fault of the EPA. This problem comes from Congress. In the setting forth of emission standards for sulfur dioxide, the amendment was really designed to protect the jobs of coal miners of the East. Therefore, the standard was set in terms of percent reduction of sulfur dioxide, based upon the sulfur originally present in the coal. EPA has now been forced to implement that standard and they came out with a proposal that would require an 85% reduction with a floor of 0.2 pounds per million BTU. The present standard, incidentally, is 1.2 pounds per million BTU. When you start examining emission standards of this sort, you realize they play a very strong role in what you might call the economic and social well being of the community. Very demanding monitoring requirements are called for with these standards. For example, if the continuous monitoring device fails, one must immediately start taking hourly measurements which require a crew of three men to be on 24-hour duty, 7 days a week. The financial burden placed upon the generating facility gets rather high, and this burden is passed along to the consumer. There is no question that the consumer will pay for it. If you add these costs to the cost of fuel and to the construction cost of electrical generating facilities, which have almost quadrupled in 10 years, you are placing an almost intolerable burden on certain elements of society. It would strike me that unless you could show there is a benefit in terms of health and aesthetics, you better very seriously reconsider standards of this sort. This standard, for example, would permit about six times higher sulfur dioxide emission level in the East, where the ambient problem is already acute, than in the West because of the difference in sulfur content in the coal.

Another problem we run into with respect to what you might call entropy induced by communication problems is a reluctance to take a definite stand. Let me give you a specific example. I have asked EPA repeatedly, if we make under the SIP a promise that the state will make a commitment, in other words, we promise, in effect, that the legislature will consider an act providing for inspection and maintenance of automobiles, and the legislature refuses to pass that into law, is this considered a violation of SIP? If it were, it would be providing EPA with a tremendous blackmail opportunity. I was interested in getting an answer; I never did. I do not know what the answer is. And this again, I think, is a vital flaw in all this planning.

It has been the practice of the EPA to delegate to the state permitting and enforcement powers, if the state so wishes. The state of Colorado, for example, has obtained delegation for the permitting of new sources. It is never requested PSD authority. The difficulty with this is that every once in a while EPA will step in and override if it decides that the state is not properly enforcing standards. The federal agency can step in and conduct enforcement itself, and has done so on occasion. I frankly wish it had done so on other occasions. We have in the western states a lumber industry which makes use of what I call waste burners. They look like teepees and most of them are old. Operators of these burners put in bark, shavings, sawdust (wet, dry, or indifferent,) start a fire, and burn the mess up. And I assure you that when this thing starts up in the morning, it is a mess. Smoke fills mountain valleys so that you can hardly see. The objection of the operators has been always that it is too expensive to put in control equipment. The operators complain that they are not sure of their timber, since they do not own it. It all comes from competitive bidding. For this reason they cannot take the chance of installing expensive equipment. So the battle has been going back and forth for some time. Two years ago, the legislature of the State of Colorado resolved the issue. It decided that any waste burner in the state that is within 75 miles of the boundry of an adjoining state shall not be subject to the regulations of the State of Colorado but, rather, that of the adjoining state. All eighteen burners are within the 75 mile limit. Yes, there is such an act, and this is why I wish the EPA had stepped in.

There is a bill now before the legislature that is designed to bring the Colorado Clean Air Act into conformity with the federal Clean Air Act Amendment of 1977. It is a bill that was written by industry, openly, unashamedly My personal feeling is if every piece of litigation that is now before the courts with respect to EPA policy under the Clean Air Act goes against the EPA, this act might meet with EPA approval. But if EPA should win one case, no. It provides, for example, that no enforcement can be taken against a source until that source has exhausted all legal avenues of appeal. We have had one case in this state in which the appeal has taken 10 years and the plant has been operating in violation for those 10 years without being subjected to any fine. The bill was written by a legal firm, hired by an association of Colorado industries.

We listened to a case last Thursday which involved a poultry waste processing plant northeast of Denver. The plant takes poultry excrement and dries it for commercial sale. We have three such plants in this state; two of them are clean and there is no problem. This one is not. The neighboring people chartered

two buses to come down to Denver to tell us what they thought about it. They didn't think much of it. The Commission revoked the permit and I asked the assistant attorney general to tell the 120 people precisely what that meant. He did; he said it meant absolutely nothing. He pointed out that this company could go into court and just delay the whole thing. When asked how long the delay could take, the answer was 10 years. One member of the audience looked at us, got up and said that we were wasting our time and theirs since we did not have any real power. And, he was right, we do not have any power.

Let me cite a specific example of how organizational entropy can make it difficult to implement air quality standards. The new act will make it even worse, since it provides, for example, that if an application is not acted upon within 20 days, it is automatically granted. There are any number of things in this proposed Colorado act which, in my opinion, are an attempt to give industry everything it wants but still retain permitting authority within the state so that EPA will no longer duplicate the permitting process. I feel an act of this kind stems largely from the uncertainty or lack of communication or organizational entropy that results in the inability of the legislator, or the Commission, or the Air Pollution Control Division to really know where they stand, to really know what is asked of them, and to really know what they might get away with and what they might not get away with. And that is very important.

We passed a regulation last fall that the EPA wanted and we felt it was proper. The regulation requires control of hydrocarbon vapors in the transfer of gasoline from a tank truck to the tank of a filling station. That is phase one hydrocarbon recovery. It costs anywhere between $500 and $4,000 per station. In the regulation, we made this requirement applicable only to those areas which are not in attainment of the ozone standard. The City of Fort Collins is in non-attainment of the ozone standard. In terms of a new standard promulgated in January, there may be up to 0.12 attainment. This regulation becomes effective February 10, 1979. Apparantly, before we can change the designation from non-attainment to attainment, we must publish a notice in the Colorado Register, wait 60 days, hold a public hearing, keep the record open for 30 days, and then make a decision to forward to EPA for confirmation. In the meantime, regulations are scheduled to be enforced February 10th on the old designation. What you are saying is 5 months later you go to these people who put in the equipment and say, "Sorry bud, you don't need it after all." What do you do? You go and ask the enforcement people not to enforce the regulation. The enforcement people warn you that failure to enforce could leave the state open to all sorts of criticism, since they are there to enforce commission regulations. We finally convinced them, but I am pointing out that this is illegal, and a citizen could bring suit, if he so desires.

Another by-product of organizational entropy is that local government has little commitment to cleaning up the air. The pressure was put upon them fairly late; they had no opportunity to evaluate strategies; and it was a failure in communication that led to this problem. But there is a further psychological difficulty. People have decided in the State of Colorado that the air will be clean if the federal standards are attained, and that attainment of these standards is enough. In other words, we have substituted the completion of a sufficient mass of paper, and our set was 18 inches high, for the desire to clean up the air. You will see local government adopting the point of view: we will do only that which is required. And EPA, in a funny way, has supported this psychological limit to commitment; not intentionally, but in a very strange way. They have said, for example, that if you live in an area that does not contain a city over 50,000, forget about total suspended particulate standards. And if you live in an area with a population of less than 200,000, forget about the ozone standards. They do not apply to you. Which again, creates feelings in many people of the artificiality of the whole process.

The entropy that I have defined as being created by communication breakdowns and other organizational problems extends to the relationship of agencies and commissions to the public. We need to be very careful about the way we solicit public support for air pollution control, as I will illustrate with a couple of examples.

We live in a democracy. If local or state government desired to go up to the EPA and refused to submit an acceptable SIP, would sanction really (in a political sense) be applied? And I will tell you, there is a strong tendency to do that. There is, however, a great reluctance to actually adopt this process. I think that this reluctance points out one of the prime essentials of this whole process. The emphasis should be based on an attempt to convince the public that it is in their own best long-term interest to clean up the air. I think that is the way to do it, rather than putting a stick in their face and saying, "We will beat you, if you do not comply."

The American public is willing to pay more for better air. They are willing to pay a certain amount out of their own pocket, but they are not willing to accept any restrictions to their automobile. And let me assure you that is true. And the Clean Air Act amendments call for just such restrictions. The public is being told that they are not going to achieve air quality standards by paying money out of their pocket. Standards will be achieved by reducing automobile usage, and even worse, by controlling growth to minimize future usage. And anybody who looks at the problem realizes that is the way it has to go. If we rely only on technology, we will not see an improvement until about 1984, 1987, or 1988 and then the whole thing will turn around and deteriorate again. I do not like to say it, but it's true. It is true in the Denver metropolitan area and for the whole Front Range area. I think the solution, speaking as an educator, is to bring the facts to the American public and convince them that the game is worth a candle. If they are willing to accept some restrictions, they will benefit, and their children will benefit.

Let me give you an example of how I think we should approach the public if we want to avoid organizational entropy. We debated using a mandatory no-drive day in Colorado. If the license number on your car ended in 1 or 2, you could not drive on Monday. If it ended in a 3 or 4, you could not drive on Tuesday. We found, to our horror, that some 60% of the families in Denver had two cars. We also found that those who did not said they would go and buy a junker for the off day. What we had really was a measure that would cut down pollution only for those people who could simply not afford to disobey the restriction.

Visibility Values: An Overview of the Problem

The two papers contained in this section provide an overview of many of the social and behavioral issues related to air visibility. Both Peterson and Flachsbart suggest specific issues which need to be studied and potential strategies or techniques for undertaking such studies.

Atmospheric Visibility Assessment[1]

George L. Peterson[2]

Abstract.--A general framework of questions in atmospheric visibility assessment is provided as well as a discussion of what it means to value visibility. Several alternative methods for measuring visibility values are summarized.

The purpose of this paper is to discuss the problem of measurement of the value of atmospheric visibility. Primary concern is for differences in visibility caused by man-made pollution. The principal context of concern is unique scenic environments such as national parks and wilderness areas.

A FRAMEWORK OF QUESTIONS IN ATMOSPHERIC VISIBILITY ASSESSMENT

There has been extensive research on the technical aspects of air pollution and the effects on atmospheric visibility (e.g., Stern, 1977). Even so, the technical picture is not yet complete. In order to assess the value of atmospheric visibility, however, we must understand the human response. Here, research seems to be less well developed. It is clear that natural phenomena such as mist, fog, haze, dust, precipitation, etc. affect people very differently than smoke and smog. Dust, even though it may be "natural," is probably different in its effect than fog. It is likely that each of these forms of impaired visibility is perceived differently and that the context of the observer strongly intervenes. The observer's belief or attitude about the origins of the impairment will also intervene. Before much progress can be made, more structure is needed for the question.

Assessment of atmospheric visibility is aimed at two primary tasks: 1) evaluation of the extent and nature of impairment of visibility resulting from human activity, and 2) evaluation of the significance or value of the impairment. The first is a matter of discerning whether and in what ways visibility has been impaired. The second is a matter of finding out who cares if impairment occurs, why they care, and how much they care. For example, if a large coal-fired power plant is proposed in the vicinity of a national park, the first problem is to assess the extent to which visibility in the park will be impaired if the plant is built. The second problem is to decide whether the expected impairment is acceptable by looking at the tradeoffs among costs and benefits with and without the power plant.

From one point of view the second question has been answered legislatively if we interpret the legislation as saying that any perceptible impairment is unacceptable. From another point of view it can be argued that real decision making processes will consider each case in terms of consequences and tradeoffs in the light of political, economic, social, and technical factors. It can also be argued that legislation is a fluid commodity, especially new legislation, and its application to specific situations will be shaped by judicial review, administrative practice, and public response. To confine the science of

[1]Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979. Parts of this paper are based on work supported by the National Science Foundation, by the Department of Transportation, and the USDA Forest Service. Thanks go also to James deBettencourt for his recent work on Threshold Utility Theory, and to Northwestern University for contributing support to our research. The support of Colorado State University and sponsoring agencies is appreciated for making the workshop possible. While most of the writing occurred prior to the workshop, subsequent revising reflect the richness of exchange that took place and for which credit may be due various participants. However, responsibility for errors, omissions, and other imperfections belongs solely to the author.

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"Atmospheric Visibility Assessment" to the first problem alone, i.e., measurement and prediction of the extent and nature of impairment, is therefore dangerous and naive. There must also be a science of measurement and prediction of the costs and benefits of the impairment.

Figure 1 is a rough outline for a framework of major research issues orbiting about the two primary tasks. Three technical tasks are prerequisite to the assessment. They are 1) description and prediction of the physical/chemical atmospheric parameters that are relevant to visibility, 2) description and prediction of the optical properties of the atmosphere, and 3) description and prediction of perceived visual images. The first two are linked to the third by means of a "psychophysical" bridge, a transformation function that predicts the perceived image as a function of the optical properties of the atmosphere. In the absence of the psychophysical bridge, visibility assessment becomes an ad hoc exercise in simulating or speculating about visual images and measuring perceptions using panels of human observers. Given the psychophysical bridge, perceived parameters can be predicted directly from simulations or descriptions of the optical properties of the atmosphere. In either case improved technology is needed in the areas of atmospheric measurement, atmospheric simulation and modelling, and visual psychophysics. Improved technologies are also needed for measurement of visual perception and simulation of visual images, including research methods as well as practical procedures. Corollary to this is a need for better understanding of the language of visual perception.

With this technical background, the extent and nature of visibility impairment can be evaluated, either through ministerial decision processes or through political decision processes. Criteria based on perception research and/or legislation can be used together with information about the natural atmospheric background. It is essential to distinguish between "natural" and "ambient" atmospheric background, because criteria applied relative to an ambient background could lead to a series of "acceptable" incremental degradations which are actually unacceptable in absolute terms. The ministerial and political decision makers who judge the extent and nature of visibility impairment will requiee information and skills on which to base their evaluation. Here, research on decision and judgement methods is important, as well as research that gleans technical literature and consolidates the findings into legible principles, facts, and procedures. There may also be workshop or Delphi techniques that might be employed to inform the decision makers. These methods might use panels of experts or panels of citizens as pluralistic advisers where the state-of-the-art is inadequate or where time and money constraints prevent the use of more rigorous studies.

The "bottom line" in the assessment is whether the predicted or described impairment is worth worrying about. It is the "so what?" or "who cares" part of the assessment. This requires application of social welfare criteria concerned with economic efficiency, social and psychological costs and benefits, and distribution among individuals and classes. Here we get into legislated standards and criteria derived from political processes and technical research on costs and consequences. Such research may take several forms, including work on "artifical" pricing, willingness to pay, psychomotivational benefits, psycho-physiological benefits, etc. Although the value of the impairment is, strictly speaking, a pure political issue, technical research on costs and consequences contributes to a more enlightened, more effective and hopefully more "beneficial" political outcome. Also, many decisions of a valuation nature are delegated explicitly or implicitly to administrative agencies, and here high quality information on costs, benefits, and distribution is imperative.

For example, the importance of distributional and contextual questions is in part illustrated by a study many years ago in Los Angeles (Van Arsdal, et al., 1964). It was found that affluent people who were least exposed to air pollution were most aware of it and most concerned about it, while poor people who were most exposed were least aware and concerned.

It has been the intent of this section to take a brief look over the whole spectrum of tasks and research needs in atmospheric visibility assessment. The paper now turns to a more specific look at the second primary task, valuation of visibility impairment.

THE VALUE OF ATMOSPHERIC VISIBILITY

Before it is possible to recommend methods for quantitative measurement of the value of atmospheric visibility, it is necessary to have an operational definition of what we want to measure. By "operational" definition we mean that it is defined in a way that allows changes in magnitude to be observed, ordered, and compared so that numbers can be assigned. First several concepts need to be sorted out.

It is necessary to differentiate between "value in use" and "value in exchange." The value in exchange of a car, for example, is

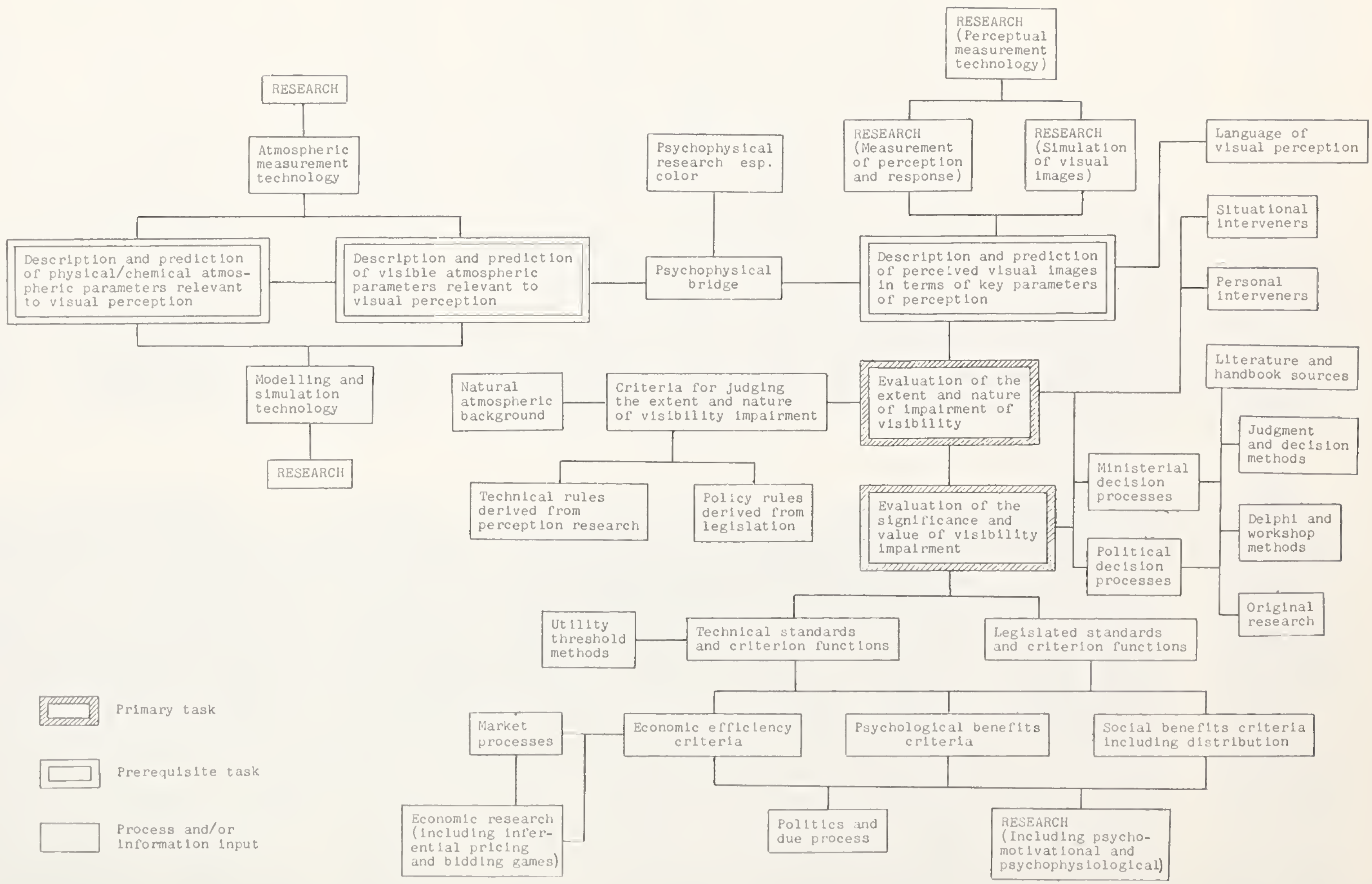

Figure 1.--A framework of research issues in atmospheric visibility assessment.

measured by the amount of money, goods or services that can be obtained in exchange for the car in the open market. It is the opportunity cost of keeping the car - the money, goods or services foregone because of a decision to keep the car rather than to exchange it. The value in exchange is dependent upon the price other people are willing to pay for the car, the price for which other people are willing to sell substitutable cars, and the availability of and demand for such cars. In other words, value in exchange is determined by the market. It is a measure of true value to society only if there is an ideal market mechanism and the distribution of wealth in society is judged to be optimal (deNeufville and Stafford, 1971, ch. 11).

Value in use is the value of the car to you, irrespective of market prices, because of the functions it performs for you. Value in use may be more or less than value in exchange. An old car may be worth only $300 on the open market, but because of your intimate familiarity with its idiosyncracies and history or because of sentimental value, you might not be willing to sell it for less than $1000.

Atmospheric visibility does not seen to be a marketable commodity. It is apparently nondivisible either in use or in production, and there is no direct market for its exchange, at least not in the context of visibility in national parks and natural areas. However, the value of a scenic view is reflected in the real estate market. The upper floors of a high-rise apartment building demand higher rents, hotel rooms with a view of the ocean are more expensive, and the homes on the hill cost more. When someone's riparian view is cut off by a new building, there is likely to be litigation. But, the values involved are a function of what there is to look at, and there are many other factors, including symbolic status and prestige and the nature of the view, which complicate this "market" for a view and make it difficult to isolate the effects of visibility. If the effects can be isolated, the prices thus derived would measure value in exchange and would perhaps reflect the exchange value lost when a view is cut off by pollution. This would also reflect market imperfections and the effects of distribution of income. While a few rich people may be bidding up the price of a view from Nob Hill, the majority of us may have quite different priorities for the allocation of our scarce money.

If we define the value of visibility as its value in use, the closest we can come to a monetary measurement is a contrived estimate of willingness to pay. It has been questioned whether meaningful estimates can be obtained through questionnaires or simulated choice techniques because of the artificiality of the experiment. People have difficulty with questions for which there is no experiential antecedent. In a study of the impacts of the proposed Cross Town Expressway in Chicago, we attempted rather naively to measure people's willingness to pay for accessibility to various neighborhood facilities and services. We found that they were unable or unwilling to play the game. They gave us responses of "acceptable" or "unacceptable" to hypothetical changes in access instead of making the monetary tradeoff that was asked of them (Peterson and Worrall, 1970). Ferment from these findings is in part responsible for our development of utility threshold theory as a means to set standards of perceived environmental quality. This approach is discussed in a later section. Even when the question represents a real choice, it is doubtful that people can answer economic questions correctly when they do not have to accept the full consequences that would ensue if they were actually making the choice. These problems point out that research on artificial pricing and willingness to pay requires very sophisticated experimental design.

Perhaps there are surrogate methods similar to the "travel cost model" in valuation of recreation resources (Dwyer, et al., 1977) which can be used to estimate willingness to pay for atmospheric visibility. However, willingness to pay for atmospheric visibility seems to be a far more elusive quantity even than willingness to pay for a "free" recreational resource. In the case of the recreational resource there is a behavioral manifestation of the willingness to pay that can be observed. It is the willingness to pay for travel to the site. Is there such an observable behavior for willingness to pay for visibility? The question reminds me of a trip I made in 1960 from Fairbanks, Alaska, to Mt. McKinley Park over the Fourth of July. It was a two-day trip. We drove down one night, spent two days and one night in the Park and drove back the third night - and it was an all night drive. The mountain is notoriously cloud-shrouded, but it was so important to us to see the top that we climbed a hill near Wonder Lake and waited all night hoping for a glimpse. In the early morning the clouds parted and we got our view, which was fully worth the price. Obviously, a high price was paid by all for that view - the willingness to forego the sleep that we desperately needed, but how much money was it worth?

While this story suggests that there may be observable behavioral expressions of willingness to pay for visibility, it also suggests that willingness to pay depends on the thing being viewed. We would not have stayed up all

night to see a common view, nor would we have spent two out of three nights driving to get to a common place. It was the magnificent Mt. McKinley, or "Denali" as it is more properly known, that we were waiting to see. It was a once-in-a-lifetime opportunity for a frustrated mountain climber to gaze at one of the greatest mountains in the world.

Apparently, we must distinguish between visibility as an instrument (or the lack of visibility as a constraint), and visibility as an end. In the former case, the value of the visibility will depend upon the uniqueness of the view.

Even if willingness to pay can be estimated by some such indirect observation of behavior, there may be serious defects in the results. Willingness to pay by itself is inadequate, because it also is dependent upon ability to pay and the "fairness" of the distribution of income in the society. A measure that is blind to distributional inequities is not adequate. The widow's mite has more "value" than the king's treasure, although to the accountant and his perspective of economic efficiency, the quantity of money may be all that matters. To be sure, the widow's mite can purchase no more than a mite's worth in the market place.

An alternative to measurement of value in use of terms of money is to use a utility theory approach and measure value in "utiles." There is no solution, because "utility" is more elusive than money. It has the appearance of ease of measurement, because in the applied literature apparently "anything goes." Put down a semantic differential scale or a rating scale or use rank order or paired comparison, or Von Morgenstern lotteries or perhaps get esoteric and use ratio scaling. Then, go to Thurstone or Stevens or somebody for scaling techniques, and presto chango, you have utility. Allegedly in some cases you have interval or even ratio scales - but what is the unit of measurement? In virtually every case the unit is idiosyncratic, and individual "utilities" cannot be compared. When individual "utilities" are combined into aggregate utility functions, double jeopardy occurs; non-commensurate units are combined and blatant political assumptions are made. The best that can come out of most "utility" measurements is a rough ordering.

Such information is of great usefullness for many things, but strictly speaking, it is not "valuation." In these experiments some behavior is being observed, usually under simulated circumstances, and the behavior is being used as an indication of motivating value, but the standard unit of measurement is missing as is the standard definition of value. Measurement is the assignment of numbers to different states of a variable such that relationships among the numbers describe relationships among the states of the variable. We need not use all the properties of the numbers, and may be satisfied with nominal, ordinal, or interval measurement. But, if the numbers are to be usable in an economic calculus such as cost-benefit analysis together with monetary values, then a ratio scale is required. If all we want is relative comparisons, then interval or ordinal measurement may be adequate. Before the measurement system can be designed, we must have <u>specifications</u> of how the numbers are to be used. These uses will define the required properties of the measurements. For meaningful interval or ratio measurements that can be used across persons and situations, a <u>standard unit</u> of measurement is required, and a <u>standard method</u> of measurement is desired. For ordinal measurement to be generalizable, a <u>standard situation</u> must be defined so that other cases can be compared with it and with each other. Without standard units, standard methods, and standard situations we are as if at the Tower of Babel where "...the Lord did confound .... the language of all the earth."

To understand value in use we must understand the uses of atmospheric visibility. These include such things as 1) viewing natural scenes, 2) visual air navigation and seeing and avoiding other objects and aircraft, 3) surface navigation, orientation, and legibility by means of visual landmarks, 4) visual communication, 5) to indicate or measure atmospheric condition and composition, and 6) (for some) to influence emotional state or attitude. Items one, three, and six, with primary emphasis on one, are important to the context of this paper.

In addition to its direct value in use, atmospheric visibility also has impacts that are of value. Changes in the intensity of solar radiation received at the surface, changes in temperature, and changes in weather and precipitation are examples of important consequences of atmospheric transparency and color. There may also be important changes in human psychology and physiology that stem from visibility. All these impacts may cause changes in plants, animals and man. These direct consequences are in addition to the other effects of chemical and physical atmospheric agents which modify visibility. For example, nitrogen dioxide and aerosols in the atmosphere may reduce visibility, cause the air to look brown, and reduce solar radiation. They may also cause other harmful effects such as the fading of textile dyes and respiratory irritation. The consequences of visibility are of concern in this paper, but the other consequences of the agents affecting visibility are not.

Another consequence of visibility occurs through its direct value in use. If the use is to view natural scenes and if impaired visibility interferes with that use, then human behavior will change. People will do less viewing at the point in question and more of something else. This may cause redistribution of income and activity.

This brief discussion of value must distinguish between optimality and adequacy in the setting of policy standards and in impact through behavior change. Optimality in atmospheric visibility may mean a total absence of man-made pollution all the time. Adequacy may mean something else entirely and may depend upon the human ability to perceive differences, the human willingness to pay for improvements, and the behavioral sensitivity to various degrees of reduced visibility.

The Aesthetics and Psychology of Atmospheric Visibility

Impairment of atmospheric visibility is not all bad. To be sure, clear, crisp and cloudless high pressure days in the Midwest provide unusual visual range and natural atmospheric color. It is thrilling and unusual to see the skyline of Chicago crisply defined fifteen miles down the lakeshore. But, the sunsets are drab on those days. Such days always close with the same pretty but unspectacular pale orange glow. The most interesting sunsets are not associated with maximum transparency of the air, and sunsets (and sunrises for the ambitious) have an important place in human psychology. In the Quetico-Superior wilderness where people go on extended canoe trips, the campsite with a view of the sunset is a prized location. Another interesting sidelight from canoeing experience is that navigation through an intricate maze of islands and lakes is difficult on extremely clear days, because of inability to perceive distance and "read" the shorelines and horizons. It is easier on hazy days when the more distant shores appear "bluer" than the nearby points and islands. Hazy or misty days also add to the mystery of wilderness by enchancing the perception of distance and remoteness. The crisp days are nice for a change, but it would be far less interesting in the wilderness if everyday was that way, and people would get lost more often.

And, there is the enchanting smell of wood smoke in the autumn, and the now rare (in cities) smell of burning leaves. There is the harvest moon that turns red in the lazy smokey air of Indian Summer. There are the many moods of the Grand Canyon - how boring it would be if every day were the same jewel of transparency, and the Grand Canyon would not seem as large or as intricate. The magic of the Great Smokey Mountains is in part created by the haze that lies almost perpetually over the area. We are enriched by the morning fog and moonlit haze of sleepy hollow, and the great fogs of London and of San Francisco, while destructive and inconvenient in many ways, are romanticized in our literature. Rain, hail, mist, smoke, fog, haze, clouds, and now smog are part of our culture, as is the clear crisp day. The answer, I think, from an aesthetic point of view, lies in the preservation of diversity in visual experience. The aesthetic value of atmospheric visibility goes up as its availability goes down. Does the value go down as availability goes up?

So, contrast is good, but if something becomes too rare, only the wealthy can have it, and the rest may not even realize that they are deprived. A couple living in Los Angeles in 1964 had never been out of the city. They drove to Las Vegas for a vacation, and on the way back their car broke down at night in the desert. When they got back they couldn't stop talking about the stars, which they had never really seen before. Indeed, the wife seemed frightened by what she had seen.

This experience also points out a kind of visibility impairment that is usually not classified as pollution. This is the nighttime atmospheric illumination that occurs near large cities because of extensive artificial lighting. You can sometimes see the aurora borealis in Chicago, except that you can't because there is too much atmospheric illumination from the city. You can't see many stars, either, and the enchantment of a moonlit vista is severely impaired. The atmospheric glow from artificial lights is also aggravated by pollution because of increased scattering of the urban light and because of extinction of the weak light from the things we might like to see if we knew they were there.

The pollution, the lights, and the closed-in buildings of our cities seem to conspire to deprive us of visual intimacy with the sky and the panoramic horizon. The artificial sounds and smells of the city also separate us from our natural heritage, and thus the value of clear air and panoramic vistas and sensory intimacy with mother earth is greater now than it has ever been.

The opportunity to experience transparent and naturally colored air is valuable. It is worth the cost of preserving it or someday only the chosen few who can journey to the moon or to Mars will know what the masses are missing by impoverished confinement to a smog-shrouded unearthly wasteland. And, while on Mars, they will wonder sadly what the view might have been

from Pike's Peak on a clear day because there are no green fields or blue lakes or alpine meadows on Mars. It has been said that the words of "America the Beautiful" were inspired by the view from Pike's Peak. These words may someday only be an historical memory.

ALTERNATIVE METHODS FOR MEASURING THE VALUE OF ATMOSPHERIC VISIBILITY

Because of the nature of the atmospheric visibility problem, it is desirable to explore several ways to measure value. In this section several strategies are suggested and briefly described. Detailed derivations, explanations, and experimental designs are beyond the scope of this paper. The strategies fall into the following categories: 1) political referendum, 2) adequacy measures based on utility threshold theory, 3) derivation of exchange prices from real estate market transactions and/or from view obstruction litigation, 4) derivation of willingness to pay from observations of actual behavior, 5) derivation of willingness to pay from observation of behavior in simulated or experimental situations, 6) measurement of utility functions by appropriate market segments, and 7) gross estimates of relative priorities by questionnaire techniques.

All of these categories presuppose that the structure of the question has been made explicit, that is, that we first 1) specify the language of visual perception and can identify, measure and describe the relevant perceived atmospheric attributes, 2) understand the species of human response, including the personal variables and types that modify response to the visual atmosphere, 3) identify the situational or contextual modifiers of human response, and 4) specify the psychophysical bridge between atmospheric conditions and perceived atmospheric attributes.

Political Referendum

With problems of this type the only truly valid answer is the one that emerges by due process as a political expression of the will of the people. Given a structure for the question, technical processes could identify the alternative atmospheric policies and consequent conditions that are feasible and the investments and sacrifices that would be required (and by whom) to implement each policy. This information then would be spread among the people, and by referendum or some other political process they would express their choice. The value of atmospheric visibility is not measured explicitly. Rather, it is implicit in the political choice. But, the choice is the desired end, because it is the policy which otherwise might be made by bureaucrats and rationalistic methods from explicit knowledge of values. If we assume that it is not possible to expose the alternatives and their costs adequately, or if we believe that the people are incapable of becoming adequately informed, or if we believe that the people cannot act rationally and do not have the right to act irrationally, or if we choose to dispute the distribution of power in society, <u>and</u> if the people ask us by political means to make the decisions for them, then we must resort to other methods, and it becomes meaningful to try to get explicit measures of social value.

I must confess that I am suspicious at this point in life that any attempt to measure "social values" by technical means that are outside market mechanisms and political processes is in serious danger of being a confusion of technical and political matters - with the possibility of pre-emption of political rights. I trust science to develop alternative means to travel to the moon, but I do not delegate to science the right to decide whether it is good to invest the resources that would be needed. If someone or some computer can demonstrate beyond reasonable doubt the attributes of omniscience, infallibility, justice, benevolence, and infinite wisdom, I will gladly place my destiny in his, her, or its hands, but I believe that the conclusion of such perfect reasoning would be that I and we must make the choices and suffer the consequences anyway, and all we would get from the "great mind" would be better information on which to base our choices.

In the absence of the perfect mind, technocratic policies and theories of social welfare are suspect. There are too many hidden assumptions, hidden preemptions, hidden fallacies, and hidden biases. The value of atmospheric visibility to me <u>is the value that I place on it,</u> as expressed by the choices and investments that I make, or would make if constraints were relaxed. The value of atmospheric visibility to society is the pluralistic resolution of our personal choices and investments. Scientific methods might be able to measure my values by observing my choices in real or simulated situations, but there is no technical means to decide how to combine my values with someone else's values to obtain a collective or communal value (Arrow, 1951).

Adequacy Measures Based on Utility Threshold Theory

Related to the concept of political referendum is the notion of a policy standard of perceived environmental quality based on a specification of the percentage of the people (perhaps a simple majority) or the percentage of a particular segment or class of the people who must find the environment to be acceptable. In choosing to accept (i.e., vote for) or not

to accept (i.e., not vote for) a given environmental configuration, a person is expressing a choice in which the value of the environment is implicit. A basis for such standards can be derived from "Utility Threshold Theory" (deBettencourt, 1979). Briefly, it is as follows: If alternative atmospheric configurations could be described in terms of the attributes of the visual atmosphere, then any given individual could be asked to accept or not accept each atmospheric configuration vis-a-vis a given use (e.g., viewing natural scenery in a national park). Presumably, the individual has an utility function which orders the value or utility of each alternative, and he prefers the alternatives in the order of their utility. At some level of utility the person becomes indifferent. This is the boundary between acceptable and unacceptable configurations. By observing the person's accept-reject behavior in experimental settings for a sufficient number of alternatives, a mathematical description of the boundary can be estimated as a function of the atmospheric attributes. Utility need not appear in the expression, because it can be defined to be zero at indifference. Of course the actual threshold isoquant will be "fuzzy" in the personal decision process, but multiple observations will allow estimation of the most likely position of the isoquant.

Because these threshold isoquants are exressed in terms of atmospheric conditions rather than utility, they can be compared and combined probabilistically across individuals. Indeed, it is not necessary at all to measure the individual threshold. One can go directly to an aggregate probabilistic distribution of the thresholds for a given population.

Given the function that describes the probability that a given atmospheric condition will be acceptable to a given segment of the people, public policy may then define the level of probability that is socially required. The feasible set of public choices is then the set of environmental configurations within the centile that has been specified as the standard. We then find the minimum cost alternative which satisfies this policy constraint (i.e., that it must be acceptable to x% of the people). Or, given a cost constraint, find the alternative that maximizes the percent of the people who will find the choice acceptable.

The method may also be developed in terms of a "standard case" rather than the zero utility datum. Here, alternative environmental situations are compared to a specified standard situation and are judged by individuals of the subject population to be better than or not better than the standard. A policy then can be set by political means as to what percentage of the population must find a given case to be better than the standard for it to be socially acceptable.

To obtain data for this method we must observe people making "accept-not accept" responses or "better than-not better than" judgments. While it may be possible to observe such choices in real situations, it probably is not practical. Questionnaire or laboratory methods must be used. For example, in our study of river recreation, we used verbal descriptions of hypothetical environmental configurations (deBettencourt, 1979; deBettencourt and Peterson, 1977). Photographs might also be used, or an adaptation of computer graphics techniques such as those used by Hammond (see U. of Colorado, 1976) for policy capturing might be employed. While the theory is well developed and seems to make sense, the real challenge seems to be in the design of the experiment so that the observed responses represent real choices. This may be a new task for each application. We have shown, for example, that children's responses to photographs of playground equipment predict real choices, reasonably well, but is this finding generalizable to adults and atmospheric visibility? (Peterson, Bishop, Michaels and Rath, 1973). This method as well as other utility theory based methods presume that the utility function is reasonably stable (i.e., that the person's environmental decisions are not arbitrary and are not predictible at least probabilistically). If the utility function is not stable, then all such methods are like measuring the positions at an instant in time of ducks in flight so that we can come back later and shoot them.

For a recent conceptual adaptation of the method to recreation and instream flow see Peterson, Honore, Howard and Lime 1979.

Derivation of Exchange Prices from Real Estate Market Transactions and/or View Obstruction Litigation

In the real estate market, many factors, including locational amenities such as view, influence exchange prices. It may be possible through systematic analysis of many transactions to isolate that component of price contributed by view in a given situation. However, to ask generically for the "price" of a view makes no more sense than to ask generically for the price of a house. It depends on which view and which house you are talking about. Furthermore, it is extremely difficult, if not impossible to separate several issues such as quality of view, atmospheric visibility, symbolic pres-

tige of location, etc., in using "hedonistic prices" to measure the value of visibility. This area of research is still very much a "frontier" activity. There are as yet no well developed and generally accepted theories or methods. For examples, see Ridker and Hennings (1967), Polinsky and Shavell (1974), and Li and Brown (1978).

It may be possible to ferret out some quasi-prices from court decisions in cases of view obstruction litigation, if indeed there are such cases. If judges or juries have awarded compensation based on estimates of lost property value or loss of value in use, then these legal measurements of value may be useful. But, it might not be clear in a given case what kind of value is being awarded, and the method for arriving at the amount of the award may be somewhat arbitrary.

Derivation of Willingness to Pay from Observations of Actual Behavior

The travel cost model was developed and has recently been re-recommended as a way to measure willingness to pay for public recreation resources which are outside normal market processes (Dwyer, et al., 1977; Ullman and Volk, 1962; Merewitz, 1966; Smith, 1975; Knetsch, 1977). The idea is that travel cost can be used as a surrogate for resource price and that the demand function can be observed in the distance decay of trip frequency to the site. That is, the farther one has to travel to the site, the less frequently one will go. The idea of finding manifestations of willingness to pay in actual behavior is a good one. Perhaps there are behaviors in response to variations in atmospheric visibility that are manifestations of willingness to pay. With a little creative thought, somebody ought to be able to find behavioral changes which, when observed, would give clues to willingness to pay. Such observations would be doubly powerful if they were unobtrusive.

To illustrate the concept of behavioral indicators of willingness to pay, consider photography. Do people take more pictures of the Grand Canyon on clear days or on foggy days? Consider viewing time. Do people spend more time at a given site viewing the canyon on clear days or on foggy days? Do more people drive to the top of Pike's Peak or over the Trail Ridge Road on clear days, do they take more pictures, and do they spend more time viewing? In Chicago, is there a relationship between atmospheric visibility and the number of people who pay for a view from the top of the Sears Tower or the Hancock Building? Do they stay longer on clear days? Do they take more pictures? Such behaviors could be observed unobtrusively through time-lapse photography, through casual observers, through body counts, or through per capita film sales. Observations could be made at many different kinds of places under a variety of atmospheric conditions. If a theory could be developed which explains the behavior as a product of willingness to pay, then perhaps willingness to pay could be estimated.

Derivation of Willingness to Pay from Observations of Behavior in Simulated Experimental Situations

Numerous studies have attempted to estimate willingness to pay for various things through questionnaires, bidding games, and other experimental techniques. This subject has been covered in Brookshire and Randall contributions to these proceedings.

Measurement of Utility Functions by Appropriate Market Segments

If the population can be appropriately stratified, then the problems of measuring, comparing, and combining utility functions are not so serious, especially if our interest is confined to ordinal relationships among alternatives. Perhaps the most promising and applicable use of such methods can be gleaned from recent research in marketing. In marketing the purpose is to understand consumer preferences, to correctly assess the consumer's willingness to buy, and even to influence the consumer's willingness to buy. The measurement of values in psychometrics and the measurement of utility in decision and judgment theory are well developed fields as is the application of these techniques in marketing.

Gross Estimates of Priorities by Questionnaire Techniques

If all else fails, perhaps it would be useful to hire the Gallup people to take a poll. Research of this sort goes on, it has a useful place in public decision making, and if properly done, it can give good results. But as Senator Chuck Percy of Illinois discovered in 1978, polls do not necessarily predict how the people will choose when the votes are cast.

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A Framework for Assessing Human Response to Proposed Impairments of Atmospheric Visibility in Class I Areas[1]

Peter G. Flachsbart[2]

Abstract.--A framework for assessing visibility impairments is developed around a general model of social impact assessment. In addition, an approach for predicting human response to impaired visibility is described.

INTRODUCTION

While the original Clean Air Act of 1970 was intended to improve the quality of air over already polluted urban areas, it did not protect those areas in the nation which already had superior air quality. Thus, in 1977 the U.S. Congress adopted amendments to the Clean Air Act in response to successful litigation brought by the Sierra Club before the U.S. Supreme Court. The purpose of these amendments is "to preserve, protect, and enhance the air quality" in Class I areas.[3] These areas consist of all international parks, those national wilderness areas and memorial parks in excess of 5000 acres, and national parks which exceed 6000 acres in size.

To remedy existing problems, states must prepare an implementation plan which identifies existing sources of air pollution which pose a threat to visibility in nearby Class I areas. These sources will be required to adopt the best available retrofit technology. To prevent future visibility impairments, federal land managers may deny permits for proposed power plants, copper smelters, wood burning operations or any other pollution source which could impair visibility in a nearby Class I area.

[1]Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

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[3]Clean Air Act Amendments of 1977, Public Law 95-95, Sec. 160, 169A.

STRATEGIC OR TACTICAL SOLUTIONS

It appears that federal land managers must seek tactical solutions to a problem which may require more emphasis on strategic solutions sought outside their jurisdiction. One argument for strategic solutions stems from the geographic nearness of some Class I areas to large urban regions. A prime example is the "brown cloud" that hovers over the growing Denver area and threatens visibility in nearby Rocky Mountain National Park. The threat of haze intruding into some national parks suggests that more attention ought to be given to developing stricter controls on the sources of air pollution in nearby urban areas. Ironically, in January, 1979, the Environmental Protection Agency relaxed the primary ozone standard from 0.08 p.p.m. to 0.12 p.p.m., because the evidence on the health effects of ozone could not justify the stricter standard.

Another argument for strategic solutions concerns the energy issue. Besides being blessed with many beautiful scenic areas, the American West also possesses 63 percent of the nation's future coal reserves (Faltermayer, 1977). Understandably, there is considerable social and political pressure to mine coal to offset imports of natural gas and oil which currently supply nearly half of all domestic demand.[4] For various reasons the electrical utilities increasingly have looked to remote rural sites for new power plants (Messing, 1978). Compared to the west coast, southern Utah, for example, offers sites unencumbered by existing development and regula-

[4]Executive Office of the President, "The National Energy Plan," U.S. Government Printing Office, Washington, D.C., April 1977, p. 13.

tions, closer to coal reserves in Colorado and Wyoming, and free of people who could complain about detrimental health effects of SO_2 and particulates. Everyone would appear to benefit including many residents of southern Utah, whom it is believed would welcome new investments in public infrastructure as an economic boon to a depressed area.

The possible exceptions to this list of beneficiaries would be native Americans on reservations near the power plants and visitors to Arches, Bryce Canyon, Canyonlands, Capitol Reef, and Zion National Parks. Native Americans could be exposed to greater health risks and park visitors on occasion might see a colored plume drift across the sky. Therefore, rather than requesting federal land managers to assess the visibility impairment potential of each new power plant, greater emphasis should be placed on the development of alternative energy resources, as well as policies to conserve energy and manage peak demand.

UNRESOLVED ISSUES

Assuming strategic solutions to this problem will be pursued, the federal land manager meanwhile will still need some assistance in assessing the potential visibility impairment in Class I areas due to new sources of air pollution. This assessment is fraught with many uncertainties and some unresolved issues. Part of the uncertainty stems from the probabilistic properties associated with atmospheric transport and diffusion of emissions from the source of pollution. Stochastic simulation models exist which should aid the land manager in estimating which views will be impaired, at which time period, to what extent, and how often given the pollution parameters of a new point source and atmospheric conditions (Latimer, 1979). However, these models are not inexpensive to validate and are accurate to a factor of two. At issue then is the question of how certain must the models be in their validation.

One can assume that these models will achieve greater powers to describe diffusion phenomena with improved levels of accuracy. There still would remain several unresolved issues relevant to the interpretation of the new law. First, must land managers protect only views which originate and terminate inside the Class I area or does their power extend to the protection of views which cross park or wilderness boundaries? Second, what constitutes the measurement of visibility impairment?

While both questions will no doubt be argued in court, the latter question is of particular interest to this paper. A visual target has both inherent and apparent contrast in detail (Williamson, 1973). Its objective inherent contrast becomes perceptive apparent contrast as reflected light from the target travels to the eye of the observer. The reflected light is modified due to the interference of light energy from the sun and the reflectance of light from the sky and ground. More importantly, particles in the air absorb and scatter light energy. The definition of an impairment depends in part upon the initial cleanliness of the atmosphere. For instance, adding contaminants to a pristine atmosphere can result in dramatic contrast changes, while the same pollution, when added to a dirty atmosphere will result in little change in contrast. Furthermore, the color of a visual target changes not only as a function of pollution added to the atmosphere, but also as a function of the target's distance from the viewer and the color of the target. In a clean atmosphere, a black target is much more sensitive to color change than an orange target as viewing distance lengthens.

These uncertainties about objective measurement of visual impairment suggest that more attention should be given to human response to both the components and Gestalt of a visually impaired atmosphere. Yet, such attention raises a third question, namely what are the dimensions of human response and how should they be measured? Specifically, federal land managers should be concerned not only with perceived visual impairment, but also with desired visibility. The cognitive dissonance between perceived and desired visibility could affect overall human satisfaction with visibility impairment. Also, the extent to which the impairment is prevented or is corrected ought to depend upon the importance or salience attached by the public to preserving aesthetic views. A related question concerns whether human response to visibility impairment can be expected to vary significantly across different observers, as well as non-observers. If so, which socio-economic, behavioral or personality characteristics of these individuals could be used to predict different types of response?

Given the emission and atmospheric characteristics of a proposed new source of pollution, one could construct a model which relates variation in human response, as modified by human characteristics and other factors, to variation in visibility impairment. If human response cannot be modeled and thus predicted then every new permit request poses an overwhelming problem in costly original research (Peterson and Gemmell, 1977). Project-specific research will not likely be funded if a permit request requires a decision in sixty days.

PROPOSED FRAMEWORK

Given the requirements of the Clean Air Act Amendments and the unresolved issues of the problem discussed previously, there is an urgent need to develop a framework of the situation which confronts the federal land manager. The framework proposed here is a slight modification of a general model of social impact assessment originally developed by Wolf (1974). The framework's components are summarized in Figure 1 and discussed subsequently.

The federal land manager must assume that every proposed project with potential for visibility impairment exists in an historical context as a solution to some societal problem. Thus, for example, power plants may be proposed to satisfy projected new energy demand. Copper smelters and scrap wood burning operations enhance the economic base of local areas. Such projects represent semi-permanent solutions to certain needs of society, and as such warrant a detailed evaluation of their threat to visibility in Class I areas. Other projects may cause only temporary visibility impairment, and as such may warrant conditional permits. For example, the practice of periodic prescribed fires in forested areas can reduce the slash and lessen the chance of disaster due to an uncontrolled fire.

Paraphrasing Wolf, visibility impairment may be defined as "a deformation in the state variables describing initial conditions." Obviously, there will be some disagreement over the definition of "initial conditions." Does it imply a pristine environment, as it may once have existed at some previous point in time? Or does it imply current atmospheric conditions which may be already polluted? Court litigations may resolve this dilemma. However, a starting point may be to establish a "best day" situation for which atmospheric conditions, solar angle, etc., all conspire to enhance optimal visibility. A further problem concerns the concept of visibility impairment. There is indeed a hierarchy of visibility impairment, such that with increasing levels of impairment the human eye loses visual clarity of texture, followed by loss of color, then line and finally form. Oddly enough, atmospheric conditions may sometimes permit clarity of texture, of color, of line and of form for a given visual target and still allow impairment in the manner of plume blight.

Given a visibility impairment, the next step would be to predict human response. Since the form of that response is multifaceted, there are several viewpoints as to how that reponse ought to be measured. A psychophysicist would argue that a 2 percent change in contrast detail is perceptible by a human being with perfect vision (Blackwell, 1946). A psychophysiologist may prefer to measure impairment as "subliminal perception," because some visibility impairments may be below one's level of awareness (Lazarus and McCleary, 1951). Their theory is that visibility impairments induce changes to one's level of arousal. These changes could be measured for example by changes in heart beat, respiratory rate, or galvanic skin resistance. Other psychologists may prefer to measure attitudinal and behavioral changes which may be induced by a visibility impairment (Shafer and Mietz, 1969). For a given observer, an attitudinal change could derive from the cognitive dissonance between his or her perception of the impairment relative to desired visibility. Some psychiatrists believe that degraded atmospheric visibility will induce some people to adopt a bad self-image (Searles, 1960). This belief is based on the assumption that the landscape is an extension of oneself.

The rate of change of visibility impairment may be just as important as an absolute change. For example, gradual impairments will probably induce passive adjustment and acclimation among most members of society, especially those who have had no previous first-hand

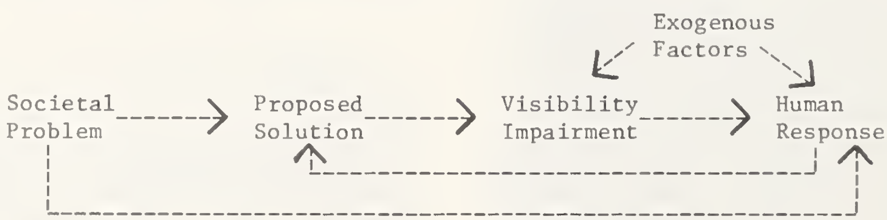

Figure 1.--A framework for assessing impairments to visibility (source: adapted from: C. P. Wolf, Social impact assessment: The statement-of the-art, man-environment interactions: Evaluations and applications, Part I, D. H. Carson, ed., Dowden, Hutchinson, and Ross, Inc., Stroudsburg, Pa., 1974, p. 11.)

exposure to these views for which protection is proposed. Alternatively, accelerated visibility impairments may cause, among some people, such a degraded self-image as to induce antisocial behavior, or at a minimum leave them feeling powerless and acted upon.

Behavioralists may argue that the degree of impairment may be reflected in reduced numbers of visitors to scenic areas. While this notion may have some validity, there are two counterarguments. First, visibility impairment results from a stochastic process involving atmospheric and emission parameters. Thus, potential visitors can be viewed as taking a risk that a popular view will be unimpaired, while non-visitors, who otherwise would be inclined to see the view, could be labeled risk-adverse. Second, the appreciation of scenic vistas represents only one of an array of motives for visits to national parks and wilderness areas. These areas offer all sorts of opportunities to campers and hikers not yet available in urban society (Bultena and Taves, 1961). Thus, more unobtrusive behavioral measures of visibility impairment may be expressed in terms of reductions in viewing time, in use of coin-operated viewing instruments and in photograph-taking behavior (Webb, Campbell, Schwartz, and Sechrest, 1966).

The model of Figure 1 also suggests some feed-forward and feedback mechanisms. The feed-forward mechanism works as follows. Societal need for the project may condition some members of the public to be more receptive to bearing lost opportunities of good visibility. The energy issue is a good illustration of this mechanism. As mentioned earlier, there is considerable political pressure to develop coal reserves in western states. One can assume that many people place a great value on the daily comforts and conveniences, which continued provision of electrical energy from vast coal reserves can supply. These same people may readily sacrifice the opportunity to enjoy a remote scenic view to the blight of a plume from a power plant smokestack. Even if they desire to see the view, their opportunities of seeing it may be slight. Of course, they may wish to preserve scenic vistas for posterity, even if they themselves have no future plans to enjoy the view. At this point comes the question of how much the public would be willing to pay to preserve good visibility in national parks and wilderness areas. Is it realistic to expect continued domestic creature comforts at current prices with no impairments of scenic views in Class I areas?

The feedback mechanism works this way. Visitors to national parks and wilderness areas and those people who subscribe to the preservation of good visibility in these areas can be expected to press for rigorous definitions of visibility impairment, with no allowances for tradeoffs or other sacrifices. Their political pressure as a public interest group may force federal land managers to deny most permits or require extensive mitigative measures in project design, location and/or operation prior to permit approval. The interesting research question here concerns the identification of those circumstances under which either the feed-forward or feedback forces will dominate decision-making.

Finally, there are exogenous factors in the model. These factors act as intervening variables to compound the problem of attributing visibility impairment and human response to that impairment to the proposed project. For example, not all visibility impairment may be due to pollution coming from the proposed project. Some air pollution has a natural origin. Over large forests of fir trees one may observe a bluish haze produced by terpenes (Williamson, 1973). These terpenes are volatile hydrocarbons emitted by the trees. This haze is evident in the Great Smokey Mountains and Blue Ridge Mountains due to the high frequency of inversions in these regions. Dust and sand storms, forest fires and volcanic eruptions are also sources of natural air pollution. Compounding the problem is the fact that human response may be favorable to some natural varieties of visibility impairment. Dust and debris hurled into the air may cause ruddy sunsets and sunrises which may impress people favorably.

PREDICTING HUMAN RESPONSE

Human response to visibility impairment is a key consideration to federal land managers in their decision-making process to grant or withhold a permit to a new air pollution source. Unfortunately, the scientific rigor required to measure human response may make its consideration in this process prohibitive due to constraints on time, money and federal staff expertise. In lieu of more rigorous approaches, federal land managers may wish to employ, whenever possible, the comparative diachronic approach. This approach, which was first presented by Johnson and Burdge (1974), is conceptualized as Figure 2. Their method of assessing future visibility impairments assumes that a proposed new source of air pollution has a historical twin for which the impairments on visibility are known or knowable. Obviously, critical assumptions and tolerances must be set with respect to what constitutes the "historical twin" of a proposed project.

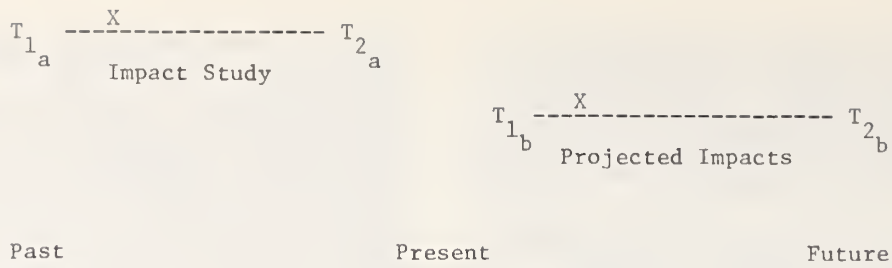

Figure 2.--Time dimensions of the comparative diachronic approach. Note: X = Source of impairment to visibility. (source: Sue Johnson and Rabel J. Burdge, Social impact statements: A tentative methodology, man-environment interactions - Evaluations and applications, Part I, D. H. Carson, ed., Dowden, Hutchinson, and Ross, Inc., Stroudsburg, Pa., 1974, p. 71.)

There are several criteria for matching twin projects for comparative purposes. First, the twin projects must be similar in terms of amounts and types of air pollution emissions. This criterion will necessitate matching projects of similar type and purpose, as well as size and scale. Second, the twin projects must exist in similar settings in terms of ecosystems, topography and atmospheric characteristics. Furthermore, the initial pollution levels of the proposed project setting must approximate, within approved tolerances, those levels of its twin prior to its construction. Likewise, the general form, line, color and texture of prime visual targets ought to be roughly the same. Third, both projects should attract observers with similar profiles in terms of the purpose of their visit. Future research may reveal also that these profiles should be identical in terms of demographic, behavioral and personality characteristics.

Given the restrictiveness of these matching criteria, the comparative diachronic method for assessing visibility impairments may be unimplementable in many circumstances. Consequently, models are needed for predicting human response to visibility impairments in Class I areas. While no such models exist as yet, research projects should be commissioned for their development. The development of these models may derive some lessons from the construction of models of human response to air quality in urban areas. An example of such a model is discussed subsequently.

Flachsbart and Phillips (1978) undertook a comprehensive approach to an explanation of human response to air quality in Los Angeles County. Their model suggested that actual air quality explained the most variance in aggregated measures of human perception of the smogginess of the air between observation sites. The best measure of actual air quality consisted of ozone and visibility, each measured as the annual number of days that its California standard had been equalled or exceeded. They assumed that variation in individual observer assessments of the degree of air cleanliness at a particular site might depend upon the socio-economic characteristics of that observer, as well as upon daily variation in ambient air quality.

Although their model is tentative and exploratory, it does suggest several factors for consideration by future research. Specifically, younger adults may be more likely to penetrate Class I areas for several days of backpacking and camping activities. Thus, more active users of national parks and wilderness areas may incur a greater predisposition to perception of a visibility impairment. A casual visitor to the area may attribute the impairment to bad luck with the weather. Furthermore, due to knowledge gained through formal education and exposure to environmental problems in the popular media, some observers may set higher personal standards for good visibility. Thus, one might expect the more educated observers to express greater dissatisfaction with a given visibility impairment, simply because they possess greater cognitive dissonance between perceived visual impairment and desired visual quality. Finally, observers with more pressing problems in life, as indexed by their race or ethnicity, may be less inclined to support the costs of pollution control equipment to mitigate visibility impairments.

It is already known that the "typical" wilderness user is an atypical member of society as a whole. A survey of seven wilderness areas in 1962 by the Outdoor Recreation Resources Review Commission concluded that the typical user had a professional occupation, with above average income and education, and resided in an urban area of 100,000 or more

population.[5] It is precisely these social characteristics of observers which may condition their response to visibility impairments. It is also these characteristics which may make this whole issue of importance to an articulate minority, who could easily be labeled elitists.

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Visibility Values: Statements of Advocates

The environmentalist's perspective of the air visibility standards issue is summarized in this section by Rudolph in his paper which contains an historical review. Hilst represents the point of view of an energy industry research professional who sounds a warning about attempting decision making in the absence of good indicators of social values the public assigns to air visibility standards.

Visibility Protection: A Historical Perspective with Suggestions for Policy Implementation[1]

Ronald L. Rudolph[2]

Abstract.--A historical overview of Congressional action on visibility is given along with the author's suggestion of four policy decisions that must be made to implement visibility protection.

BACKGROUND

The recognition that air quality, in particular visibility, is an integral part of our natural heritage, represents an important evolutionary advancement in a uniquely American idea. That idea was the preservation of large tracts of land (and now the air above them) unused, uninhabited, and essentially unaffected by the influence of people, for the enjoyment of present and future generations. The culmination of this idea, a national park system and wilderness preservation system, grew from the vision of many people who saw great virtue in setting aside some of the best of our natural heritage.

Congress established the National Park System (NPS) in 1961. It directed the NPS to manage the national parks in such a way as to (among other things) "converse the scenery... in such manner... as will leave them unimpaired for the enjoyment of future generations."[3] In the past, scenic resources (most importantly visibility), unlike water, wildlife, geologic, forest, and cultural resources, were not explicitly protected by NPS policy or regulations. This past oversight by the NPS is easy to understand. Until rather recently it was hard to imagine that man's industrial activities would foul the air of a Yosemite or Yellowstone.

Since the 1950's the damage done to air quality has been rather easy to see. For example, in 1960 visibility across the Rio Grande Valley was about 200 miles. By 1968, air pollution inversions reduced visibility to 30 miles, a loss of over 600 percent.[4] Visibility decreased 10-40 percent in most parts of the eastern U.S. from the mid-50's to the mid-1970's.[5] During the same period, visibility in the southwestern U.S. decreased 10-30 percent, mostly due to emissions from copper smelters and coal-fired power plants.[6] In fact, pollution, mainly from surrounding coal plants, at times reduces visibility in the Grand Canyon to less than 15 miles.[7] A visitor would be hard pressed to see across the canyon under such conditions.

National concern about air pollution culminated in the passage of the Clean Air Act in 1970. The Act directed EPA to take measures necessary to "protect and enhance" the nation's air quality.[8]

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[1]Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

[2]Ronald L. Rudolph, Energy Coordinator, Friends of the Earth, 124 Spear, San Francisco, California 94105.

[3]39 Stat. 535.

[4]David W. Tundermann, Senior Staff, Council on Environmental Quality, "Protecting Visibility: The Key to Preventing Significant Deterioration in Western Air Quality," October 1977.

[5]John Trijonis and Kung Yuan, "Visibility in the Northeast: Long-term Visibility Trends and Visibility/Pollutant Relationships," Grant No. 802815, Environmental Sciences Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, 1978.

[6]John Trijonis and Kung Yuan, "Visibility in the Southwest: An Exploration of the Historic Data Base," Grant No. 803896, Environmental Sciences Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, EPA-600/3-78-039, April 1978.

[7]Tundermann, p. 1.

[8]42 U.S.C. 7401(b)(1).

In the opinion of some people, EPA's regulations did not go far enough in protecting those areas of the country with relatively good air quality. EPA's regulations would have allowed a uniform polluting of the Union's air. For instance, the air over Glacier National Park would have been allowed to resemble that of East Chicago.

Environmentalists took EPA to court. In 1973 the U.S. Supreme Court upheld environmentalists' claim that Congress intended to prevent degradation of air quality in those areas of the country with pollution levels lower than the federal air quality standards.[9] Thus, EPA was required to develop "prevention of significant air quality deterioration" (PSD) regulations.[10]

For determining what levels of deterioration were significant, the regulations established an area classification system--Classes I, II, and III. In Class I areas, very small increases in sulfur dioxide or particulate concentrations were considered significant; in Class II areas, moderate increases; and in Class III areas, increases up to the federal standards were allowed. The regulations classified all areas of the country Class II, but gave the states, Indian tribes, and federal government the authority to redesignate their lands through a specified process.

It soon became apparent, however, that EPA's PSD regulations would not prevent serious smog problems in areas of national scenic importance. For example, in the Southwest, electric utilities, backed by projections of the Federal Power Commission, envisioned building 50 new coal-fired power plants by the turn of the century. The frightening damage done to air quality in the Southwest by only a handful of existing coal plants, notably the infamous Four Corners and Navajo power plants, did not seem to deter the utilities, or the Department of Interior which would have to review and issue permits for the proposed plants.

The Interior Department's apparent lack of concern, manifested by its refusal to redesignate the Southwest's "Golden Circle" of national parks to their proper Class I status, became critical when a consortium of utilities announced plans to build the world's largest coal-fired power plant adjacent to Glen Canyon National Recreation Area (and within shouting distance of the Navajo plant).

[9] Fri. v. Sierra Club, 41 U.S.L.W. 4825 (1973).

[10] 40 CFR 52.01,52.21;39 FR 42510 (Dec. 5, 1975), amend 40 FR 25004 (June 12, 1975), 40 FR 42012 (September 10, 1975).

According to the Interior's own studies, the pollution from the proposed 3,000 megawatt Kaiparowits power plant would have caused violations of the Class I SO_2 increment at Capitol Reef, Bryce Canyon, and Grand Canyon Recreational Area.[11] If built, it would have inevitably teamed up with the Navajo plant's pollution, furthering the Los Angelization of the Grand Canyon. Nonetheless, all signs at the time indicated that Interior would most likely approve the Kaiparowits projected.

Fortunately, by April 1976, wide spread public opposition, and a lack of electricity demand, forced the proponents of the project to cancel their plans. Their action, however, did not stop the momentum behind the growing effort to assure protection of the air quality resources of the nation's scenic treasures.

The Clean Air Act Amendments of 1976 and 1977

During 1976, Congress started revising the Clean Air Act. Among the most controversial issues (along with automobile emission standards) was PSD. Congress was determined to add legislative guidance on the issue, in part because of Interior's woeful performance during the Kaiparowits controversy.

In 1976 the House and Senate overwhelmingly approved amendments that established mandatory protection for the air quality of national parks and wilderness areas. Both chambers designated these areas as Class I. They also established a preconstruction review process that required a source to obtain a PSD permit before starting construction. The review process was designed to assure that, in most cases, a source would not be built if it would violate a Class I increment.

The Senate went beyond the strict increment review and provided a second layer of protection for parks and wilderness areas--the air quality --related values test. It provides that even when a source can demonstrate that it would not violate a Class I increment, the federal land manager still has an "affirmative responsibility" to protect the air quality-related values (including visibility) of the Class I area.[12] This could lead to a denial of a PSD permit.[13] (The connection between PSD and visibility will be treated in depth later in this paper in the section on reviewing new

[11] U.S. Department of the Interior, National Park Service, Denver Service Center, "Analysis of Kaiparowits: Powerplant Impacts on National Recreation Resources," March 1976.

[12] 42 U.S.C. 7475(d)(2)(B).

[13] 42 U.S.C. 7475(d)(2)(C)(ii).

sources.) Similarly, even if a source would violate a Class I increment, it could still get a PSD permit if the federal land manager is convinced there would be "no adverse impact on the air quality-related values" of the Class I area(s) effected.[14]

The statutory language relating to the increment review and the air quality-related values test is very important to the visibility issue. The denial of a PSD construction permit based on the increment review would be due to excess concentrations of "particulate matter" or "sulphur dioxide."[15] A permit denial based on the air quality-related values test, however, could be based on concentrations of any "emissions."[16] Therefore, the presence of those pollutants for which PSD increments have not been set (e.g., sulfates, nitrates, organics) could result in no construction of a source if its impact would damage air quality.

The increment review and air quality-related values test eventually became part of the Clean Air Act, but not before the Clean Air Act Amendments of 1976 were filibustered to death on the last day of the legislative session. The filibuster was led by Utah Senator Jake Garn. Senator Garn's main objection to the bill was the PSD section. He opposed mandatory protection of Class I areas because he felt PSD classification was a matter for the states to decide, and believed that Class I status for the national parks in Utah would limit coal plant siting options in that state. As we shall see, Senator Garn's filibuster backfired.

The period between 1976 and 1977 legislative sessions gave proponents of the PSD provisions time to reevaluate the proposed amendments. Substantial evidence presented to the House Commerce Committee indicated that even mandatory Class I designations would not adequately protect visibility. For example, one study found that visibility could be reduced 40% even when the Class I numbers (standards) were met.[17]

To remedy the inadequacies of the 1976 bill, the House, led by the wisdom and courage of Congressman Paul Rogers, Chairman of the Commerce Committee's Subcommittee on Health and the Environment, adopted the Visibility Protection provisions, Section 196A of the Clean Air Act Amendments of 1977.

The visibility provisions established as a national goal, "the prevention of any future, and remedying of any existing, impairment of visibility in mandatory Class I federal areas."[18] Visibility impairment was defined to include "reduction in visual range and atmospheric discoloration."[19] Congress directed EPA and the states to identify those sources which are contributing to visibility impairment. Those identified will be required to install the "best available retrofit technology"[20] no later than 5 years after EPA approves a state's implementation plan.[21] It also directed the states and federal government to work out a 10-15 year strategy for repairing existing and preventing future visibility impairment.[22]

IPP - The Shape of Things to Come

The air quality-related values test (including visibility) was in essence applied in a major energy facility siting decision shortly before Congress approved the Clean Air Act Amendments of 1977. The proponents of the Intermountain Power Project (IPP), a 3,000 megawatt coal plant, proposed to site the fossil burning giant 8 miles east of Capitol Reef National Park. IPP's planners obviously did not have air quality impacts in mind when choosing their site. In fact, according to Secretary of the Interior Cecil Andrus, IPP's "sole environmental constraint was the avoidance of visual impact of the plant on traffic using Utah Route 24."[23]

IPP would have used Capitol Reef and Canyonlands National Park as an atmospheric garbage can. Even the plant's proponents admitted that the project would have caused numerous violations of the Class I sulphur dioxide increment.

Secretary Andrus gave IPP a clear signal that the project was not particularly favored at Interior. He stated, "I think we must recognize that this site, so close to a

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[14] 42 U.S.C. 7475(d)(2)(C)(iii).

[15] 42 U.S.C. 7475(d)(2)(C)(i).

[16] 42 U.S.C. 7475(d)(2)(C)(ii).

[17] House Committee on Interstate and Foreign Commerce, Report on the Clean Air Act Amendments of 1977, H. Rep. No. 95-294, 95th Congress, 1st Session, p. 205 (1977) (hereinafter cited as House Report).

[18] 42 U.S.C. 7491(a)(1).

[19] 42 U.S.C. 7491(g)(6).

[20] 42 U.S.C. 7491(b)(2)(A).

[21] 42 U.S.C. 7491(g)(4).

[22] 42 U.S.C. 7491(b)(2)(B).

[23] Letter from Secretary of the Interior, Cecil Andrus, to Senator Alan Cranston, June 7, 1977.

national park, presents serious difficulties."[24] He let it be known that he was firmly committed to "appropriate actions to assure that the unique natural values of these lands (national parks) are properly protected."[25]

Further resistance to the IPP came when the President's Council on Environmental Quality let IPP know that they could probably not count on any Presidental intervention on behalf of the project. A senior staff member of CEQ wrote, "if forced to, the President's strong desire to protect national parks and wilderness areas may suggest what the White House inclinations might be..."[26] IPP found a new site, far from any critical environmental areas.

IMPLEMENTING VISIBILITY PROTECTION

There are major policy decisions that must be made implementing the visibility protection provisions of the Clean Air Act. Four major ones will be addressed below: 1) the definition of visibility impairment; 2) achievement of the national visibility goal for views from within Class I areas to points outside the area; and 3) the merits of developing a national, several regional, or many individual visibility standards to meet the legislative intent of the statute.

Definition of Visibility Impairment.

The statutory definition of visibility impairment "include(s) reduction in visual range and atmospheric discoloration."[27] Thus, by law, it appears any visibility standard will have to include visual range as one method for determining impairment.

Some reviewers, however, argue that changes in contrast (as opposed to visual range) are much easier to measure and are what people actually perceive. These reviewers think contrast changes should be given more weight in the development of the regulations. Friends of the Earth agree that contrast should be one measure used to determine visibility impairment, however, the relative importance of contrast is hard for us to judge without a better technical knowledge of the atmospheric physics and chemistry involved.

We would also like to see the social sciences brought into the development of the visibility standards to give us a better understanding of how people react to impairment of visibility.

Some people contend that Congress intended that visibility impairment must be "significant" before regulatory actions (e.g. application of BART, tighter emissions limits for new sources, relocation of plant sites) become applicable. In other words, impairment would have to be noticeable for an extended period of time (greater than 1 hour) during the day, and for a specific number of days during the year.

Friends of the Earth find there is no statutory basis for considering the notion of "significant" impairment in the development of the visibility regulations. Unlike the PSD provisions of the law, wherein Congress explicitly determined what constitutes "significant deterioration,"[28] and even provided for limited variances from the Class I SO_2 increment,[29] Section 169A (or its legislative history) contains no such qualifiers. The language is plain. The national visibility goal is the "prevention of any future, and the remedying of any existing" visibility impairment (emphasis added).[30] Therefore, the criteria for defining visibility impairment should be any measurement or perception of reductions in visual range, atmospheric discoloration, contrast, or any other method used to qualify visibility.

Review of New Sources.

Congress apparently rejected the idea of two separate permitting processes for PSD and visibility. The Conference Committee stated that "issues with respect to visibility as an air quality value in the application to new sources are to be resolved within the procedures for the prevention of significant deterioration."[31]

Congress chose to couple the Class I increment review, the air quality-related values test, and the new source visibility requirements into the PSD air quality review. Below I will suggest how this should work, particularly with respect to permit decisions

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[24] Id.

[25] Letter from Secretary of the Interior, Cecil Andrus, to Senator Edmund S. Muskie, June 5, 1977, Congressional Record, June 9, 1977.

[26] Tundermann, p. 12.

[27] 42 U.S.C. 7491(g)(6).

[28] 42 U.S.C. 7473(b).

[29] 42 U.S.C. 7475(d)(D).

[30] 42 U.S.C. 7491(a)(1).

[31] Conference Report, Clean Air Act Amendments of 1977, "Joint Explanatory Statement of the Committee on Conference," H. Report No. 95-564, 95th Congress, 1st Session, Congressional Record, August 3, 1977, H8550.

involving sources that would not violate the Class I increments, but would cause visibility impairment.

First, let us again consider cases in which a proposed source would violate a Class I increment. In such cases, the state or EPA would be prohibited from issuing a PSD construction permit unless the applicant could convince the federal land manager that there would be "no adverse impact on the air quality-related values" of the Class I area(s) involved.[32] The federal land manager would essentially have the power to veto the PSD permitting authority.

Let us assume that in the overwhelming majority of cases involving Class I violations the federal land manager would act to protect air quality. If he did, no permit could be issued, and no construction could take place.

Second, let us examine those cases in which a proposed source would meet the Class I increments. Under this condition, the state or EPA could issue the PSD permit, unless the federal land manager "demonstrates to the satisfaction of the State" (or EPA) that the source would impair air quality. [33] The land manager would have to override authority in such cases.

The federal land manager could seek to overturn the issuance of a PSD permit if he felt the state did not adequately consider his concerns. In fact, the Senate Public Works Committee encouraged the federal land manager to seek court relief for such "inappropriate permits" as a means of excercising his affirmative responsibility.[34]

Friends of the Earth believe the land manager's duty to protect air quality values does not end with the filing of a PSD law suit or a court finding that the permit was issued properly. The law and its legislative history indicate that the federal land manager must use the full power of his office, including denying the rights-of-way, disapproving mining plans, declaring lands unsuitable for mining, and declaring lands as areas of critical environmental concern. The use of these other powers would be especially critical in cases where there would be no Class I violation but would be visibility impairment.

The legislative history of PSD and visibility established that complying with the Class I increments would not necessarily be sufficient to meet the air quality-related values test or the new source visibility requirements. The House Commerce Committee recognized this when it concluded that "the mandatory Class I increments ... do not protect adequately visibility in Class I areas."[35] Furthermore, the Conference Committee recognized that "merely meeting Class I increments under the prevention of significant deterioration will not be adequate to assure visibility protection."[36]

At the same time the federal land manager was directed to "protect federal lands for deterioration of an established values, <u>even when the Class I numbers are not exceeded</u>" (emphasis added). [37] The land manager should "assume an aggressive role in protecting air quality values of lands under his jurisdiction."[38] Moreover, "in the case of doubt, the land manager should err on the side of protecting air quality related values for future generations."[39]

Congress' great emphasis on the pivotal role of the federal land manager protecting the air quality-related values of Class I lands, bestows upon the land management agencies a very "powerful tool."[40] This authority should be applied in making visibility goal a "national commitment, which is nationally enforceable."[41]

Friends of the Earth contend that unless an applicant can demonstrate to the satisfaction of the federal land manager that the emissions from a proposed source will not have an adverse impact on the air quality-related values (including visibility) of a Class I area, the federal land manager is obligated to seek a relocation of the project. In short, the manager should use whatever administrative authority available that will be effec-

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[32] 42 U.S.C. 7475(d)(2)(C)(iii).

[33] 42 U.S.C. 7475(d)(2)(C)(ii).

[34] Senate Committee on Environment and Public Works, Report on the Clean Air Act Amendments of 1977, Senate Report No. 95-127, 95th Congress, 1st Session (1977), p. 35 (hereinafter cited as Senate Report).

[35] House Report, p. 205.

[36] Clean Air Conference Report (1977); Statement of Intent; Clarification of Select Provisions, <u>Congressional Record</u>, August 4, 1977, H8663.

[37] Senate Report, p. 36.

[38] <u>Id</u>.

[39] <u>Id</u>.

[40] <u>Id</u>.

[41] Clean Air Conference Report (1977); Statement of Intent; Clarification of Select Provisions, <u>Congressional Record</u>, August 4, 1977, H8663.

tive in protecting air quality. If the land manager is restricted from using his other authorities he could find it impossible to exercise his "affirmative responsibility".

EPA has acknowledged that this approach would be a legitimate way for the federal land manager to caary out his affirmative responsibility.[42] While the PSD regulations do not require the land manager to withhold non air-related permits, neither do they prohibit such actions.

We suggest that EPA's forthcoming visibility regulations should contain a mechanism that will require the federal land manager to use appropriate administrative powers to prevent visibility impairment. The State Implementation Plan process would be the most sensible approach. States should have to adopt an enforceable procedure for the land manager to excercise his affirmative responsibility to prevent impairment of visibility.

Views from Within Class I Areas to Views Outside.

A controversy has developed over whether Congress intended to protect against visibility impairment only within Class I areas, or whether it also sought to protect views from within Class I areas to points outside the area.

It is clear to Friends of the Earth, that Congress intended to protect views outside Class I areas, such as from Mesa Verde National Park to Shiprock, New Mexico. That vista, long regarded as one of the most spectacular in the Southwest, is frequently obscured by the plume of the Four Corners power plant.

The millions of people who are attracted to the "breathtaking panorama(s)" and "scenic vistas"[43] of our national parks and wilderness areas do not limit their vision to sights within park boundaries. To do so would be like watching a movie with part of the screen covered. To restrict visibility protection only within Class I areas would also ignore the role of the night sky in the appreciation of visual values.

I firmly believe that only considering views within Class I areas would not offer the protection Congress intended. If, however, EPA decides to the contrary, will the agency issue visors to people visiting, say, Inspiration Point overlook at Byrce Canyon National Park? Such artifical aids would be necessary to restrict people's view and help them avoid seeing the obnoxious haze created by the Navajo power plant.

National, Regional, or Local Visibility Standards.

There is some debate about whether the visibility standard(s) should apply on a national, regional, or local level. A national standard would make little sense unless it would protect visibility in all parts of the country. For example, small concentrations of pollutants added to relatively polluted areas in the East would not be visible, while the same amount added to the cleaner air of the west would have very noticeable adverse effects. A national standard could not achieve the national visibility goal without taking into account such regional differences.

Area specific and even vista specific standards have been advocated by some people. Such approaches are not without merit. However, the amount of data required to evaluate existing visibility conditions for each area, let alone the effort needed to develop individual standards, is in orders of magnitude beyond the current capabilities of EPA and the land management agencies. Even with these necessary data, the development of area specific standards has the potential to be a cumbersome regulatory nightmare. Furthermore, such an approach would most likely delay for some time the implementation of the visibility protection program.

Regional visibility standards appear to be the most reasonable approach. This is especially so in the areas of the Southwest and Northwest which contain the majority of Class I areas, and where the air is of similar quality over large areas. Regional standards could be augmented by area specific ones as the necessary information became available.

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[42]Preamble to EPA's PSD regulations (40 CFR 52.21), 43 FR 26402 (June 19, 1978).

[43]House Report, P. 204.

Visibility Impairment: Ours, Theirs, or His?[1]

Glenn R. Hilst [2]

Abstract.--This paper presents a brief overview of the component parts of the system, physical and social, which must be considered in any rational attempt to control visibility impairment attributable to anthropogenic sources of pollution. An attempt is made to assess the current state of understanding, knowledge and information for each of these components, and the consequences of error, ignorance and uncertainty when these analyses are used for the practical purpose of emission control strategies to achieve visibility objectives. The weakest links in the system are judged to be 1) the lack of quantitative measures of visibility impairment, 2) the lack of agreed-to standards or acceptable levels of visibility, and 3) the lack of reliable theoretical and empirical methods for attribution of visibility impairment to specific pollutant sources.

INTRODUCTION

John and Mary Doe and their two teenage children have just completed a two week camping trip in one of our national parks and are recounting their experiences in the comfort of their surburban home in the midwest. To a person, they allow they had a great time - vacations are neat, and this one had been fun. Of course, the hassle of freeway traffic, the overheated engine on the high passes, and the noisy campers next door for a couple of nights were not part of the fun - but that's the way the ball bounces. The two rainy days were a nuisance, but were to be expected - and the maps, reading materials, and writing of long over-due notes had filled the hours. Then of course there was the day they had hiked to the top of the nearby ridge only to find the view of the distant mountain range was blurred by something in the air. Two days later, they were told, the view was magnificent.

Perhaps, as he turned off the lights and buttoned up the house for the night, John wondered briefly about that hazy day back there in the mountains. But it had been a good vacation. Now it's back to work on Monday - and, oh yes, the quarterly property tax bill is due next Tuesday. Wonder what we'll do for vacation next year? Maybe the Grand Canyon? The Worths said the Canyon had been hazy the day they stopped by on their way to L.A. But the Joneses raved about the view when they were there. We'll see - better have the car tuned up and check on that cooling system.

Is this little vignette from the lives of the Does typical? Is their perspective on visibility in Class I areas what we are talking about in this workshop? The answers to those questions are probably "yes" and "no" - yes, the Does are included, but they are not necessarily "typical," and across the nation's population of Does, individual perspectives on hazy days in Class I areas range from righteous indignation to total indifference. And with that the stage is set for pollsters and pundits, politicians and socio-economists, and, of course, workshops and scientific inquiry. I do hope, however, that the Does will somehow stay in the picture; after all, they are the ones affected, and they will surely pay the bill for anything that is done about visibility in Class I areas (or anywhere else.)

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[1] Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

[2] Glenn R. Hilst, Senior Member, Technical Staff, Electric Power Research Institute, P.O. Box 10412, Palo Alto, California 94303.

OUR TOOLS FOR VISIBILITY CAUSE AND EFFECT ANALYSES

The law of the land says that visibility is an important property in Class I areas, is to be restored, if presently degraded, and is to be protected from any future impairment attributable to human activities. Further the law stipulates that impairment to visibility includes both reduction in visual range and atmospheric discoloration. The implication is that "visibility" as defined by these two properties should be maintained at those levels which would obtain if no human activities could affect a Class I area. Unfortunately, this leaves the natural baseline of visibility, from which impairments should be measured, highly uncertain. The natural variations of visibility are large; how do we separate out the anthropogenic component? Our historical records of visual range were designed for airport operations, and airports are located near population centers. Quantitative methods for measuring atmospheric discoloration are a recent development. And now the additional properties of "clarity" (sharpness?) and "texture" are being introduced as important properties of visibility. Couple these ambiguities with the person-to-person variations in visual acuity and color discrimination (topics which Ron Henry will discuss), and we have a real need for a much improved and agreed to set of quantitative measures of this thing called "visibility." Rational pollution control strategies demand such definitions, even if a qualitative "acceptable" or "unacceptable" rule can be devised for social and psychological purposes.

Now, let us assume that desired properties a la visibility can be put in place, and acceptable standards for these properties can be enunciated; how well equipped are we to translate these into optimum (least social and economic costs) strategies for pollution control? In this area there is good news and there is bad news. Certainly the brightest spot in this whole picture is the state of knowledge regarding atmospheric optics. If you will specify the visual targets, the atmospheric loading of particles and gases, the latitude and longitude, the day and the hour, the optical properties can be calculated in excruciating detail, at least for a cloud-free day. Now for the bad news; how well can we specify all those input terms and assign the particle and gas loadings to their parent sources? Which are natural (HIS) and which are anthropogenic (OURS and THEIRS)? These are the bottom line questions, when everything else is in place, the answers to which dictate rational control regulations.

I shan't belabor you with the complexities of source identification, atmospheric transport, dilution, chemical transformation, and deposition losses which must be dealt with in this problem area. Just let me say that the theoretical approaches are inadequate and empirical information is in its infancy. We have wisps of information here and there, but any generalization from these fragments is fraught with peril. Tomorrow's observations will surely change the picture and the conclusions. We at EPRI are mounting what is, by industry standards at least, a massive program to obtain regional information in this area, and other studies are going forward as well. But these will take time to produce useful results. In the meantime, we must live with error, ignorance and uncertainty.

CONCLUSIONS

In conclusion, I would like to return, very naively, to the theme of this workshop. It seems to me that a great deal of attention is being paid to the use of surveys, polls, and bidding games in the attempts to assign values to visibility. I hear little or no mention of retrospective studies which might uncover value judgments people have applied in the past through their decisions and actions in visibility related activities. For example, do the uses of park and recreational facilities bear any discernible relationship to visibility trends in those areas? I am told these retrospective studies are loaded with interpretative pitfalls (unless there is a clear and unambiguous cause and effect relationship.) But ambiguity is itself a measure of the perspective and complex value judgments which people bring to problems of this kind. Perhaps the Does actions betray their judgments more precisely than what they say.

Visibility Values: Some Management Perspectives

Papers in this section reflect the viewpoints of management people who must administer or provide technical services for agencies affected by visibility legislation. Zeller and Wagner, as well as Paulson, summarize much of the current work on visibility undertaken within their perspective agencies. Torrence, speaking as a land manager, raises some practical questions concerning air visibility standards, including what to do about natural causes of air pollution.

Bureau of Land Management Visibility[1]

Karl F. Zeller and William W. Wagner[2]

Abstract.--A brief description of the Bureau of Land Management's Visibility Impact Assessment is provided.

INTRODUCTION

The Bureau of Land Management is a federal agency that manages 453 million acres (59% of all federal lands located primarily in the western states and Alaska. These lands range from barren desert expanses to heavily forested areas. Land use activities which result in the degradation of air quality (including visibility) include: the leasing of lands for coal mining, oil shale development, and geothermal power generation; land exchange for power plant siting; leasing for mineral developments; right-of-way agreements; and off-road-vehicle races. In addition to making decisions with the potential to allow pollution, BLM may eventually be required to protect the visibility over ten proposed Class I prevention of significant deterioration (PSD) areas under BLM jurisdiction.

VISUAL RESOURCE MANAGEMENT

Prior to the 1977 amendments to the Clean Air Act (PL 95-95), which requires visibility protection in Section 169A, the BLM initiated a visual resource management (VRM) program under the authority of the Federal Land Policy and Management Act of 1976 (PL 94-579). The BLM VRM program is described in detail in BLM Manual No. 8400. Essentially the VRM program classifies a given area of land into one of five categories based on the evaluation of scenic quality (the degree of harmony, contrast, and variety within a landscape), visual sensitivity (the relative degree of user interest in scenic quality and concern and attitude for existing or proposed changes in the subject landscape features relative to other areas), and distance zones (the separation of areas into foreground, middleground, background, or seldom-seen). The five categories range from Class I where any proposed action must not attract attention to the characteristic environment, to Class V where change is needed or change may add acceptable visual variety to an area.

The BLM VRM system uses a "contrast" rating system to determine the extent of visual impact for an existing or proposed activity that will modify any landscape feature. "Contrast" in the VRM system is defined as the effect of a striking difference in the form, line, color, or texture of the landscape features being viewed compared to these same features under the effects of a proposed activity.

Once all the classification terms are understood, surprisingly similar number ratings for a particular scene are derived by different individual observers similiar to the reproducibility of the Ringelmann smoke procedure.

BLM VISIBILITY IMPACT ASSESSMENT

At present the BLM VRM system does not deal with air pollution caused visibility deterioration. BLM does, however, have an interim suggested format to follow for PDS Class I situations as part of its planning system. BLM Manual 1605 lists an interim suggested format (paragraph .45B3i) for discussing visibility. Appendix 15 of BLM Manual 1605 lists these requirements and is reproduced in Table 1.

[1]Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

[2]Karl F. Zeller, Air Resource Meteorologist, Bureau of Land Management, Denver Service Center (D-350), Building 50, Denver Federal Center, Denver, Colorado 80225.

William W. Wagner, Air Quality Specialist, Bureau of Land Management, University Club Building, 136 East South Temple, Salt Lake City, Utah 84111.

Table 1. -- BLM Visibility Evaluation Criteria

The following social and physical criteria should be applied to each proposed action potentially impacting federal areas where visibility may be an important value:

A. Social

1. Does the area possess scenic values that are important to public enjoyment? Inventory and discuss social impact on each area. Discuss existing legislation and possible PSD area redesignations. Does the legislation for the potentially impacted areas indicate that scenic value was an important consideration for establishing the area?

2. Are any sweeping views of background features, panoramas, or views of middleground or background features present, as opposed to only views of foreground features less than 1-mile distance, e.g., streamside, trailsides? Inventory and discuss impact.

3. Do natural sources causing visibility restrictions seriously affect the ability of the public to appreciate visibility as an important value in any of the potentially affected areas. Inventory and discuss. For those areas in which natural sources of visibility impairment seriously affect public appreciation of scenic values, is the magnitude of the scenic value sufficient to warrant protection from man-caused sources?

4. Discuss the potential visual impacts to visitors in any potential Class I area (includes views from Class I area to sights beyond boundary of the Class I area).

5. Discuss any other potentially important impacts on the social aspects of visibility deterioration as a result of the proposed action.

B. Physical

Since there are no existing guidelines for assessing the scientific aspects of visibility deterioration, a certain degree of latitude will be necessary from project to project. The following is offered as guidance.

1. National Weather Service (NWS) visibility data for NWS stations exists. This visibility data is not always usable due to the subjective observing techniques and target thresholds used. The recorded weather occurrence associated with each NWS visibility observation may be useful as an indicator of visibility reducing phenomena at that location, e.g., natural (blowing dust, sand, fog, etc.) or man-made (smoke, haze, smog, etc.) visibility reducing phenomena. A summary of this type information would be in order when it is available.

2. The size and nature of resulting aerosols predicted as a result of a proposed development will also affect visibility at different levels of degradation. An inventory of type and quantities of aerosol in relation to size, make-up and chemical potential would also be in order.

3. The color distribution of distant vistas is very important; therefore, reduction in color contrasts to scenic views due to light-absorbing gases or particles (e.g., soot, or nitrogen dioxide which absorbs blue light) should be addressed.

4. Loss of visibility (background contrast) due to scattering of light by sulfates, nitrates, fly ash, or any other aerosol resulting from pollution should be addressed.

5. In some cases, air pollution studies have been carried out in selected areas and visibility related measurements (nephelometer, photographic, etc.) are sometimes available. These studies should be evaluated for use in visibility impact determination.

6. There are several visibility models available that related particulate concentrations to visual range. Although BLM recognizes that the use of these models may be limited in the quantifying of visual impacts, their use is certainly in order.

In summary, the intent is to provide guidance in order to pursue a reasonable interim approach in assessing the social and physical impact of potential visibility reductions associated with proposed actions affecting federal lands.

FIELD VISIBILITY STUDY

The Utah State Office of the BLM has been involved in several major impact statements on proposed major emitting facilities. In order to assess visibility impacts BLM initiated an interagency agreement with EPA Region VIII and NOAA to study baseline visibility and to more adequately define atmospheric visibility effects resulting from natural phenomena and from man's energy development activities. A unique opportunity existed in east-central Utah to evaluate visibility in an area without extensive human and industrial activity but with the potential for progressive power plant activity, coal mining activity, and related population growth. A visibility study was initiated in November 1976 on Cedar Mountain, an elevated site some 30 miles southeast of the Huntington power plant and 20 miles east of the Emery complex. There are several other proposed power development sites within 100 miles of the area. Measurements have been taken for two-week periods during each quarter since November 1976. A complete analysis of all the data has not been accomplished to date.

The BLM is looking forward to receiving scientific and regulatory guidance from the EPA and other sources including this workshop, in order to help merge air pollution visibility criteria into the BLM VRM system.

Some Perspectives on Visibility and Land Management[1]

Neil R. Paulson[2]

Abstract.--An outline of a Forest Service visibility assessment study and summary of goals are provided along with an appendix containing the form used.

INTRODUCTION

The Forest Service, as you may or may not know, is composed of three branches: National Forest System, State and Private Forestry, and National Forest Research. National Forest System manages the National Forests and Grasslands. State and Private Forestry provides assistance to state and private forest and rangeland organizations. Lastly, National Forest Research provides research services to both public and private forest and rangeland managing units. I work for the National Forest System and Doug Fox works for National Forest Research.

The Forest Service welcomes the opportunity to participate in this workshop. It is clear there is a need to begin to evaluate the social value of visibility as a part of the implementation of visibility requirements contained in Sections 165 and 169-A of the Clean Air Act. It is encouraging to see the interagency cooperation that has gone into the funding of this workshop. The Bureau of Land Management and National Park Service provided support, in addition to National Forest System and Forest Research. I am looking forward to an interesting and worthwhile program.

Section 169-A of the Clean Air Act contains a series of very tight due dates. USDI came very close to meeting the due date for the 169-A(2) Visibility Value Study for Class I areas. It doesn't look like any of the other dates will be met. In fact, it seems that the program is gradually falling further and further behind schedule.

I really don't think that being behind schedule is all bad. Visibility is a new and very complex subject. Neither regulatory nor land managing agencies yet have the information needed to write proper regulations for visibility management in Class I areas. Land managers do not have an experience reference to draw upon for visibility as they have for managing campgrounds, rangelands, timber, ski areas, etc. Neither do the people in regulatory agencies.

Because of this it seems wise to not rush ahead too fast. A slower pace than is specified by the Act will allow collecting better data, better analyses, better judgments, and ultimately, better regulations. There needs to be time to identify and include the benefits coming from sessions like this one.

One thing that federal land managers (FLM's) really appreciate is EPA's establishment of a Visibility Work Group, which includes FLM's as well as other disciplines, to assist them with the visibility study for Congress and the regulation promulgation. This has led to a strong cooperative effort.

As I mentioned earlier, land managers have begun the difficult task of integrating visibility management into their program. The Forest Service is no exception. We have strived to describe how visibility should be managed on the National Forests. We have completed one national study and submitted our findings to EPA for consideration.

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[1]Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

[2]Neil Paulson, Air Quality Management Officer, USDA Forest Service, Aviation and Fire Management Staff, P.O. Box 2417, Washington, D.C. 20013.

We brought in a person from the field on a detail to lead the national study. Its purpose was to develop visibility management goals that could be applied to the Class I National Forest lands, and hopefully to Class I lands managed by the NPS and FWS, and submit them to EPA for consideration.

Let me briefly describe our study process to you. As I said, it was led by a detailer, Jerry Hutchins, a Recreation Staff person from our Pacific Northwest Region. He worked closely with John Bachman of EPA, John Byrne of the NPS, and many other people to develop and implement the study process we used. The NPS and FWS generally adopted our study plan and applied it to their Class I lands. The steps in it were:[3]

I. To describe the current status of visibility in each Class I area including:

- A. Present visibility management objectives for the area identified in management plans or other documents, if any.
- B. Present manmade sources of air pollution which may significantly affect visibility.
- C. Known causes of natural visibility impairments, e.g., dust, fog, etc.

II. To identify sources of visibility impairments, if any, the months they occur, and the months the situation is acceptable.

III. To identify the important vistas in each area, the viewing distance for them, the clarity of the view, and a judgment whether or not the view is desirable or undesirable.

IV. To describe the management considerations applicable to each area:

- A. Plans for a prescribed natural fire program in the Class I area.
- B. Plans for a prescribed fire program adjacent to the area.
- C. The importance of using prescribed fire as a management tool to meet resource output targets assigned to the agency.

V. To write a visibility management goal(s) for each area, considering the full range of management responsibilities assigned to the agency by law.

VI. To assemble the goals from V. above into logical groupings if possible to reduce the number of goal statements.

[3] See Appendix I for the form used for the study.

Following the completion of the study by the Regions, Jerry Hutchins met with each Regional representative and helped finalize their reports. The Regional reports were evaluated by a team in the Washington Office (WO) to attempt to further consolidate the goal statements into one or more broad national goals. The WO team consisted of two forest supervisors, a wilderness specialist, a land management planner, an air management specialist, and Jerry Hutchins.

The team wrote the following three national goals covering all of the Forest Service Class I areas after reviewing and discussing the Regional goals and consulting with several of the Regions:

Goal A: Maintain or improve the present quality of visibility within mandatory Class I Federal areas on a best day basis (the day of least natural impairment) so that:

1. Manmade air pollution from one or a combination of major stationary sources will not reduce a normal person's ability (with correctable 20/20 eyesight) to clearly distinguish form, line, color, and texture of the landscape of the Class I area at a distance of 5 miles from any point within the area, and;

2. If color and texture can be clearly distinguished for 5 miles within a Class I area there usually is a visibility benefit looking out of the area. Generally it should be possible to distinguish form and line at a distance of 50 miles.

States in which National Forest Class I areas Goal A would apply are:

Arizona	Nevada
California	New Mexico
Colorado	Oregon
Idaho	Washington
Montana	Wyoming

Goal B: This goal is for areas where natural haziness impairs visibility more than it does in Goal A. Meet the standard in Goal A to clearly distinguish form, line, color, and texture at a distance of 5 miles.

It is not practical to expect to be able to distinguish form and line at a distance of 50 miles because of natural haziness and flatter terrain.

States in which National Forest Class I areas Goal B would apply are:

Arkansas
Minnesota
Missouri
New Hampshire
Vermont

Goal C: This goal is for areas where natural haziness impairs visibility more than it does in Goal B. The ability to clearly distinguish form, line, color, and texture is reduced to 3 miles.

As in Goal B, it is not practical to expect to distinguish form and line at a distance of 50 miles.

States in which National Forest Class I areas Goal C would apply are:

Alabama	Tennessee
Georgia	Virginia
North Carolina	West Virginia

The Forest Service has a visual resource management system complete with a comprehensive series of handbooks. The BLM has a visual resource system that is essentially the same as ours. Adding visibility to these established and successful resource management systems seems desirable and logical. The terminology and techniques are familiar to field people. The system defines the key elements of the visual resource, which is what is important to visibility management, i.e., it tells what is important to be seen. The next step is to supplement it to say how and when the visual resource needs to be seen.

With that I'll close and will do my best to respond to any questions you may have.

APPENDIX I

I. CURRENT STATUS OF VISIBILITY

MANAGEMENT IN THE AREA

A. State the visibility objectives identified in the approved wilderness management plan. If none, so state.

B. List present manmade air pollution sources which may significantly affect visibility in the area.

SOURCE	Distance in Miles
1. General Urban	
2. Specific (List)	

C. Identify known causes of natural haziness in the area.

Atmospheric Moisture	______
Suspended Vapor	______
Turpines & Hydrocarbons	______
Smoke	______
Dust	______
Other (List)	
____________________	______
____________________	______
____________________	______

II. POLLUTION IDENTIFICATION

A. SMOKE PLUMES

1. Within the Area

	NOT PRESENT	PRESENT: non-point; intermittent; or temporary source	PRESENT: point; permanent; or stationary source
a. current situation		J F M A M J J A S O N D	J F M A M J J A S O N D
b. acceptable situation		J F M A M J J A S O N D	J F M A M J J A S O N D

2. Outside the Area Viewing into the Area

a. current situation	J F M A M J J A S O N D	J F M A M J J A S O N D
b. acceptable situation	J F M A M J J A S O N D	J F M A M J J A S O N D

2. Inside the Area Viewing out of the Area

a. current situation	J F M A M J J A S O N D	J F M A M J J A S O N D
b. acceptable situation	J F M A M J J A S O N D	J F M A M J J A S O N D

B. BANDS OF HORIZONTAL DISCOLORATION

	NOT PRESENT	PRESENT: non-point; intermittent; or temporary source	PRESENT: point; permanent; or stationary source
1. Within the Area			
a. current situation		J F M A M J J A S O N D	J F M A M J J A S O N D
b. acceptable situation		J F M A M J J A S O N D	J F M A M J J A S O N D
2. Outside the Area Viewing into the Area			
a. current situation		J F M A M J J A S O N D	J F M A M J J A S O N D
b. acceptable situation		J F M A M J J A S O N D	J F M A M J J A S O N D
3. Inside the Area Viewing out of the Area			
a. current situation		J F M A M J J A S O N D	J F M A M J J A S O N D
b. acceptable situation		J F M A M J J A S O N D	J F M A M J J A S O N D

C. NATURAL HAZINESS

1. Within the Area

NOT PRESENT	PRESENT
	J F M A M J J A S O N D

2. Outside the Area Viewing into the Area

NOT PRESENT	PRESENT
	J F M A M J J A S O N D

3. Inside the Area Viewing out of the Area

NOT PRESENT	PRESENT
	J F M A M J J A S O N D

III. IMPORTANT VISTAS

A. WITHIN THE AREA

LOCATION			CLARITY*		
(1) VIEW FROM (PLACE)	(2) VIEW TO (PLACE)	(3) DISTANCE IN MILES	(4) CURRENT SITUATION	(5) DESIRABLE	(6) UNDESIRABLE

* CLARITY: (S) SHARP & DISTINCT
(I) INTERMEDIATE CLEARNESS - REASONABLE CONTRAST EXISTS
(B) BARELY TO NOT DISCERNIBLE - NOTICABLE LACK OF CONTRAST

B. OUTSIDE THE AREA

VIEWING INTO THE AREA

LOCATION			CLARITY*		
(1) VIEW FROM (PLACE)	(2) VIEW TO PLACE	(3) DISTANCE IN MILES	(4) CURRENT SITUATION	(5) DESIRABLE	(6) UNDESIRABLE

*CLARITY: (S) SHARP & DISTINCT
(I) INTERMEDIATE CLEARNESS - REASONABLE CONTRAST EXISTS
(B) BARELY TO NOT DISCERNIBLE - NOTICABLE LACK OF CONTRAST

C. INSIDE THE AREA

VIEWING OUT OF THE AREA

LOCATION			CLARITY*		
(1) VIEW FROM (PLACE)	(2) VIEW TO PLACE	(3) DISTANCE IN MILES	(4) CURRENT SITUATION	(5) DESIRABLE	(6) UNDESIRABLE

* CLARITY: (S) SHARP & DISTINCT
(I) INTERMEDIATE CLEARNESS - REASONABLE CONTRAST EXISTS
(B) BARELY TO NOT DISCERNIBLE - NOTICABLE LACK OF CONTRAST

IV. MANAGEMENT CONSIDERATIONS

A. Does area have an approved wilderness fire management exception plan? YES_____ NO _____

B. Does area have either an approved fire management plan or an approved land management plan with fire direction? YES_____ NO _____

C. Describe relative importance of utilizing fire as an option to assure ecological balance which considers management direction for the ecosystem, reducing adverse affects of a major conflagration, or as a tool in forest management practices, both in the area as well as in the general forest.

Very important in order to meet assigned output tartets _____

Important in meeting assigned output targets _____

Not necessary in order to meet assigned output targets _____

EXPLAIN:

V. VISIBILITY GOAL

The Organic Act, Multiple Use Act, Wilderness Act and National Forest Land Management Act all give direction for management of National Forest Lands for a wide and diverse number of uses and activities. The Clean Air Act as amended August, 1977, states "...as a National goal the prevention any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from manmade air pollution..." It further states that "...the Federal land manager and the Federal official charged with direct responsibility for management of such lands shall have an affirmative responsibility to protect air quality (including visibility) of any such lands within a Class I area...."

Considering legislation, current levels of manmade pollution, natural impairment, wilderness management objectives, public desires, critical vistas, user attitudes and forest management considerations briefly state the visibility goals for:

A. Within the Area

B. Outside the Area Viewing into the Area

C. Inside the Area Viewing out of the Area

VI COMBINATIONS

Some Areas may have similar visibility goals. Review goals for each and if appropriate suggest logical groupings of areas by:

	AREAS
MOUNTAIN RANGE	
STATE	
REGIONALLY	
OTHER (SPECIFY)	

PREPARED BY:____________________ DATE:______________

RECOMMENDED BY:________________ DATE:______________

APPROVED BY:___________________ DATE:______________

Federal Land Managers and Visibility[1]

Jim Torrence[2]

Abstract.--The perspective of a Federal Land Manager is provided which includes concern over how important visibility protection should be in light of the many demands placed on the use of Federal lands.

I was asked to participate with you at this workshop so that you could have some understanding of what a Federal Land Manager is and what he does. In particular, most of you are aware of the responsibilities given to us as a group under the 1977 version of the Clean Air Act. I would like to very briefly outline for you what those responsibilities are and how we, at least, in my region of the Forest Service, expect to discharge these added responsibilities. From our perspective there are two provisions of the Clean Air Act which will provide major concerns for my agency. First are the considerations under the Prevention of Significant Deterioration (PSD) part C section of the act. The second involves control of pollution from federal facilities part A Section 11.

As essential element in our air resource management is the recognition that we are both sources and receptors of air pollution. We conduct activities which generate pollution at the same time that the health of the natural ecosystems we manage may be endangered by sources outside our management influences. The 1977 Act tells us that each office, agent, or employee of the federal government must "comply with federal, state, interstate, and local requirements, administrative authority, and processes and sanctions respecting the control and abatement of air pollution in the same manner and to the same extent as any nongovernmental entity." This requirement applies to both substantive and procedural (including recordkeeping, reports, permits, etc.) requirements of the various authorities mentioned. We of course will comply with this requirement. It is only fair that any activity we conduct be subject to the same requirements as the private sector. The Act in fact classifies for us the need to involve ourselves with the State Implementation Plan and other air quality control agency activities which in the past we have done largely on a voluntary basis. Along with the requirement to follow procedural requirements will come increased attention on air quality. I will return to this subject in some depth shortly.

Clearly the responsibilities we have been given under the PSD part of the Clean Air Act strengthens our ability to deal with sources of pollution outside our normal influence which pose a threat to the natural resources we are entrusted to manage. I imagine you all know as much or more than I do about the PSD responsibilities but I will take a few moments to discuss them anyway so we all recognize what I mean. The Act classified land areas according to how much deterioration of air quality would be allowed in these areas. Recognize, therefore, that this Act is a major piece of land use legislation. Class I areas, all national parks above 6,000 acres and wilderness in existence prior to August 7, 1977, above 5,000 acres, are basically locations where effects of air pollution will not be tolerated. Class II areas, all other federal lands where air quality is better than the ambient standards, allow some minimal impact. We recently went through an exercise of identifying Class I areas which also require protection under the visibility section (169 A) of the Act. All the Class I areas were deemed to have visibility as a significant value. The fact that this determination concluded that virtually all Class I areas required visibility protection is significant, I think, because it illustrates the nature of the wilderness concept and of our legislative mandates to manage such lands.

[1]Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

[2]James F. Torrence, Deputy Regional Forester, Resources, USDA Forest Service, Region 6, 319 Southwest Pine Street, Portland, Oregon 97208.

Simply stated our wilderness areas are managed such that man's influence in the areas are minimized. This is not easily done and, in fact, must at times be compromised. The reason for stating this is to suggest that our Clean Air Act responsibilities are basically a continuation and extension of our wilderness area responsibilities and we will deal with them in the same manner. Let us consider two areas of major concern to us which, I think, serve to illustrate my point, namely fire and recreation. Clearly, in order to minimize the impact of man on a wilderness we should not allow man to enter that wilderness! Such a thought, however, is politically, indeed socially, unacceptable. Therefore, we compromise by allowing no motorized vehicles and no construction of facilities. We further carefully monitor usage amd make efforts to limit our use to disperse users throughout the entire area and to maintain the appearance of no human involvement. Often this involves a rather substantial effort. Consider fire. We have a responsibility granted many years ago to protect forest resources from destruction by wildfire. Now we have come a long way in learning about the role fire plays in natural ecosystems. In many of these fires represents a perfectly natural force which should not, indeed cannot be suppressed. Fire can also be a terribly destructive force ruining resources and endangering human life. So with these thoughts in mind, what should we do about fire in wilderness areas? You must remember that our job is to provide a steady output of resources from the areas surrounding a wilderness and that a major wildfire could easily totally disrupt this output of resources. Actually our fire management policy has become rather sophisticated in the last few years. Without going into a lot of detail we determine the cost effectiveness of a fire suppression activity along with the environmental positive and negative impacts and base our decision to suppress and the level of suppression action on our integration of each of these factors. With this background you might be able to suggest a logical approach to wilderness fire. First, ask if the fire is "natural" in origin or is it man-caused. Clearly if it is man-caused it is an impact of man in the wilderness and should be suppressed. Caution should be exercised not to create more damage than the fire in this suppression, however. But if the fire is natural, lightning-caused for example, what should we do? Actually our decision is based upon a number of factors. If life or private property is endangered, recognizing that stopping a wildfire at the border of a wilderness is much like trying to stop a freight train traveling at 60 MPH at a rail crossing, action will be taken to suppress the fire. It gets a bit difficult when all other aspects of the fire are acceptable, even strongly positive with regard to the ecology, except that smoke from it will travel down valley and sock in a major resort complex. The "man's impact on wilderness" concept suggests we should allow the fire to burn. The State Air Pollution Control Agency however will site us for burning without an open burning permit. So in many of these situations we again compromise the wilderness concept because of an overriding social (political) factor. I have just provided two areas where our legislative responsibilities must be altered by basically public needs. It seems, therefore, likely that we will approach Class I air quality consideration in much the same manner. Namely our decisions with regard to air quality impacts will be made in the social/political world. Where there is a clearly demonstrated negative impact we will fight to protect the wilderness. Where there is no demonstrated impact and the public strongly supports the development we will likely allow it to be constructed.

But let me get back to visibility specifically in the context of air quality related value. I do not know right now how aggressively we must protect visibility. I hope I can learn at this conference something about how we might approach this question. We do however know something about visibility protection. For many years we have been providing a recreation experience for a large segment of the American public and we have not done this without learning something about its preferences. Every district ranger in the Forest Service knows which vistas are important to recreationists. This information has even been quantified in our Forest Service manual guidelines on landscape architecture. Our manual in this area suggests specific numbers and concepts, such as line, texture, and form which must be preserved in a vista. As Neil Paulson has already mentioned, we have taken advantage of this experience in responding to EPA's request for information as visibility values. One thing I would like to see discussed here, and as I said I don't presume to know the answers, is the relevance of this information to the subject of visibility protection and the focus of this workshop.

Really wilderness represents only a very minor portion of our activities and before concluding I would like to raise a few points with regard to our primary activities. As a multiple resource agency we set objectives for each of the resources we manage. We manage range lands to produce forage for cattle and habitat and food for wildlife. We manage forest land to produce water, wildlife habitat, and timber. In my region we grow and harvest a great deal of timber, in fact, about four

billion board feet annually, or enough to construct about 530,000 houses. This timber is only one of many resources provided by the national forest lands albeit in my area. It is probably the major resource. Please keep in mind that we are not robber barons who rape the land for profit. Indeed we operate under a number of legislative mandates to provide a "substantial yield" i.e., we cannot harvest more timber than is being produced. The level of resources utilized on a particular forest is determined not by those of us in the Forest Service acting unilaterally, but rather by a rather substantial planning effort whose primary function is to display alternatives that are compatible with the ecosystems "carrying capacity" (ability to produce the resource) and from which the public can choose a level of output. We are tightly constrained to do only what has been approved by such a process. So we do what the public demands of us, managing our natural ecosystems such that we can accommodate these demands. Although we are fortunate to be dealing with renewable resources, like any other industry we must operate cost effectively and as responsible citizens. The production of timber causes wastes--nonmerchantable wood fiber material--which has to be disposed of. If it is simply left in place it creates a number of adverse effects not the least of which is a large fire hazard. The currently most cost effective and naturally acceptable (from ecological consideration) mechanism of disposing of this harvest residue material is to burn it. We burn it under very carefully controlled conditions, but one thing it produces is smoke. Timber production is not the only reason we burn. Range ecosystems must have fire run through them to improve nutrient cycling on a regular basis. Wildlife habitat improves since edible vegetation replaces less desirable vegetation quickly following the fire. In fact, the U.S. Fish and Wildlife service routinely uses fire as a habitat tool. Bureau of Land Management uses fire much the same as we in the Forest Service do and the Park Service has recognized the natural role fire plays by establishing a policy which discourages fire suppression in many locations in national parks. However, along with all the good fire does come some negative aspects. How do we deal with smoke from this so called prescribed burning? In particular, should it be considered as impacting the national goal of visibility protection discussed by Congress? In the remaining few minutes I would like to present my arguments why it should not.

First, burning of wood fiber is a perfectly natural activity. Wood has burned since God created it and lightning. Wood will continue to burn almost oblivious to man's feeble attempts to suppress it. I don't know how many of you have seen a forest wildfire. When it is running there is really nothing man can do to stop it. So the point is, visibility reduction resulting from forest fire is really as natural as fog. To my mind it makes as much sense to suggest regulating fog as to regulate visibility reduction due to fire. The visibility issue is concerned with major stationary sources. Fire is a highly intermittent and temporary source, it does not occur in the source location twice and for any particular site has a fairly long frequency of occurrence (often 20-100 years) associated with it. The particles produced from a forest burn are not particularly rich in sulfate and nitrates which seem to be the most responsible for long term offsite visibility reduction. So what am I asking? For a free ride? Am I saying we can pollute the atmosphere with our prescribed fire programs because "wood smoke is good smoke?" No! Definitely not. We recognize our responsibility, in particular, Section 118 on federal compliance. We recognize that smoke from prescribed fire causes an impact on air quality, in particular, on ambient concentration of fire particles. We work through our local state control agencies to minimize the impact of this smoke. We conduct meteorological studies and run models to predict smoke impacts and adjust our proposed burning accordingly. Research efforts, such as the project headed by Doug Fox, are developing advanced technology to deal with this issue. We are in short fulfilling the requirements of Section 118.

Smoke from forest burning does indeed cause visibility degradation, however, we feel that it is not a causative factor in the deteriorating visibility in the eastern United States of the concern for protection of scenic vistas in the southwestern United States. We support programs to reverse these trends through our PSD-related affirmative responsibilities. We also feel that effects of smoke from forest fires should continue to be treated through the ambient air quality consideration of state agencies. In short, smoke-related visibility reduction is natural and as such can only confuse any visibility standards or goals developed. We, therefore, suggest that smoke from forest burning be specifically excluded from consideration of visibility standards.

The Visibility Problem: Physical and Psychophysical Considerations

The presentation by Malm provides a review of several physical parameters involved in assessing air visibility quality. As such, the paper provides an introduction to the physical aspects of visibility. Contributions from Latimer and Henry provide a number of suggestions for methods, and research strategies, which could relate quantitative estimates of human judgments of scenic quality to parameters of physical impairment of air quality.

Visibility: A Physical Perspective[1]

William Malm[2]

Abstract.-- This paper reviews the interpretation and measurement of variables related to visibility. The selection of 1) variables that appropriately characterize visibility and 2) instruments that measure these variables must be integrated with our understanding of what happens when a person views distant scenes. The process by which we see distant objects is based on characteristics of the object, its surrounding, the air quality and the illumination of the sight path, and the eye and the brain. Additionally, visibility is an integrative parameter in that the ability to "see" depends on all types of aerosol in the atmosphere as well as on all aerosol contained in the sight path. When establishing a standard, some consideration should be given to choosing a variable that is representative of that quality of the environment that requires protection as well as a variable that can be monitored directly. Classically, visibility has usually been interpreted as visual range, which, roughly speaking, is the distance an observer would have to back away from a target before it disappears. Visual range cannot be measured directly nor is it necessarily representative of what an observer "sees". A documentation of apparent target contrast or color change may be a better way to characterize visibility. Contrast and color change can be monitored directly and both depend on integrative long path measurements.

INTRODUCTION

The Clean Air Act Amendments of 1977 (CAAA-77) adopted the three-class incremental system of air quality for the prevention of significant deterioration (PSD) which the Environmental Protection Agency (EPA) has evolved since 1970. Class I assumes that almost any degradation of air quality (presently defined in terms only of sulfur dioxide and particulate matter) may be significant; Class II allows degradation by increases in pollution which would accompany well-planned growth; Class III assumes that there may be areas identified after elaborate processes are followed in which pollution up to the National Ambient Air Quality Standards (NAAQS) is permissible. The Clean Air Act sets three standards for air quality:

1. Primary ambient standards - to protect human health.

2. Secondary ambient standards - more stringent; to protect human welfare, plants, animals and objects.

3. Prevention of significant deterioration - to protect air quality which is better than the two ambient standard levels.

CAAA-7 delineated a large number of federal parks and wilderness areas for mandatory Class I status.

CAAA-77 provides two types of protection for the air quality of Class I areas. The first of these is PSD (see Sections 160-165 of the Act) which causes elimination of emissions from new major emitting facilities (MEF's) of SO_2 and total suspended particulates (TSP) to levels below those which would produce adverse impacts on air quality related values, including visibility, of Class I areas. Other poll-

[1]Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

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utants such as photochemical reactants and the oxides of nitrogen may be added in the future as EPA makes determinations about these.

This paper addresses the second type of protection provided by the visibility protection section (see 169A) of the amendments which deals with Class I areas where visibility is an important value. This section also applies to existing pollution problems in such areas.

The Congress declared as a national goal "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas where impairment results from man-made air pollution."

Visibility can be broadly defined as the degree of clearness of the atmosphere. The study of visibility and its relationship to meteorology and atmospheric aerosol content is an abstract, complex, and in many cases semiquantitative science.

The World Meteorological Organization (WMO) (1971) Sec. 10.1.1 defines daytime visibility as follows: "Meteological visibility by day is defined as the greatest distance at which a black object of suitable dimensions, situated near the ground, can be seen and recognized, when observed against a background of fog or sky." The WMO (1971) also defines a Meteorological Optical Range (recommended in 1957) as: " the length of path in the atmosphere required to reduce the luminous flux in a collimated beam from an incandescent lamp at a colour temperature of 2700°K to 0.05 of its original value, the luminous flux being evaluated by means of the photopic luminosity function of the International Commission on Illumination (CIE)."

Traditionally, visibility has been defined in terms of distance from an object that is necessary to produce a minimum or threshold contrast between that object and some appropriate background. Threshold contrast refers to the smallest difference between two stimuli that the human eye can distinguish. In reality, the absolute threshold is a difference between the minimum stimulus which produces a sensation and no stimulus at all. The measurement of these quantities depends on the nature of the observer, his or her physical health, mental attitude of attention or distraction, and the effects of boredom and fatigue.

The WMO (1971) suggests that the threshold contrast value 0.025 should be used for daytime visibility. This value relates well to black targets 1/2° or more in angular size when the location of the target is not known to any greater precision than $\pm 4°$ (using the Taylor (1964) vision data for daytime and 1/3 second duration).

Use of a contrast threshold value of 0.05 to compute visual range from measurements of photopic apparent contrast, beam transmittance or attenuation coefficient seemed to compare to concurrent daytime visibility ranges reported by Douglas and Young (1945), Duntley (1948), and Middleton (1952).

However, most authors have used a contrast threshold of 0.02 to determine visual range. Consequently, for ease of comparison between calculations of visual range made in this paper and those reported by others, a threshold contrast of 0.02 will be used.

Although visibility is often defined in terms of visual range, with its reasonably precise definition, visibility is really more than being able to see a black target, or any target, at a distance for which the contrast reaches the threshold value. Visibility also includes seeing targets at shorter distances than the visual range and being able to appreciate the details of the target, including colors. Therefore, the definition of visibility and the selection of methods of monitoring visibility should relate to these different aspects of 'seeing' distant objects.

DEFINITIONS AND MEASUREMENTS OF PHYSICAL VARIABLES RELATED TO VISIBILITY

In order to deal quantitatively with "visibility", it is necessary to define quantities that describe the physical phenomena related to the measurement of light transmission. Crittenden (1923) refers to light as "radiant energy evaluated in proportion to its ability to stimulate our sense of sight."

The human eye has a characteristic response to different wavelengths. Maximum response to a unit energy of light is at the wavelength of 550 nm (5,500 A). When light is studied in terms of the response of the human eye, photometric concepts and units are used. The corresponding radiometric concepts and units are used in the discussion and measurement of light energy in an absolute sense. Radiometric and photometric concepts and units are used in the discussion and measurement of light energy in an absolute sense. Radiometric and photometric concepts of importance in the discussion of instruments are listed in Table 1.

The importance of air quality impact on visibility, "the seeing" of distant objects, is based on the ability of aerosol to scatter and absorb image forming light as it passes through the atmosphere. The loss of image forming light is proportional to S and A, the atmospheric scattering and absorption coefficients. The combined effects of scattering

Table 1.--Radiometric and photometric concepts and units

Radiometric concept	Symbol	Units	Photometric concept	Symbol	Units
Radiant energy	U	Joule	Luminous energy	Q	talbot
Radiant flux	P	watt	Luminous flux	F	lumen
Radiant intensity	J	watt/steradian	Luminous intensity	I	lumen/steradian
Radiance	N	watt/m^2 steradian	Luminous	B	lumen/m^2 steradian
Irradiance	H	watt/m^2	Illuminance	E	lumen/m^2

and absorption will be referred to as attenuation (extinction) and α will be used to represent the attenuation coefficient. While S is proportional to the total amount of light scattered in all directions, σ , the volume scattering function is proportional to the amount of light scattered in a specific direction. The path function, N_* is a measure of the amount of light scattered from an infinitesimal volume of atmosphere in some specific direction. The subscript is used to suggest the light reaching the volume is from all directions and that N is point function. ${}_tN_r$, the apparent radiance incident at an observation point located a distance r from some target, is a measure of light energy reaching an observer who is viewing a target in a specific direction. ${}_tN_r$ is then, the sum of the inherent radiance of the target ${}_tN_o$, and the light scattered by the intervening atmosphere $N_r{}^*$. $N_r{}^*$ is usually referred to as the path radiance. Contrast, C, is defined as the difference between target radiance and some background radiance, ${}_bN_r$, divided by the background radiance. The ratio of the inherent to apparent contrast is contrast transmittance (T): a measure of the ability of an intervening atmosphere to transmit contrast.

INTERRELATIONSHIP OF VARIOUS MEASUREMENT TECHNIQUES

Telephotometers, measuring target and sky radiance (${}_tN_r$ and ${}_sN_r$) at various wavelengths, allow for a direct calculation of contrast transmittance (T) as well as the color of various targets. Nephelometers, polar or integrating, measure the volume scattering function σ or scattering coefficients respectively of a small volume of atmosphere. Transmissometers measure either a spatially averaged vertical or horizontal attenuation coefficient (α).

Traditionally visual range has been the parameter used to discuss or characterize visibility. Most authors assume that visual range can be calculated using:

$$V_r = 3.9/S \tag{1}$$

Where V_r is the visual range. Some of the assumptions that must be made in the derivation of equation 1 are:

(1) absorption coefficient is zero,

(2) attenuation coefficient does not vary in horizontal direction (homogeneous atmosphere),

(3) earth is flat,

(4) object is viewed horizontally,

(5) object is black (i.e., $C_O = -1$), and

(6) sky radiance is the same at the object as it is at the observing point.

The sixth assumption is dependent on the second, third, and fourth assumption as well as on the illumination of each scattering volume.

The impact of these assumptions on the calculation of visibility will determine the type of measurements needed to characterize visual range. A first order model (multiple scattering was not accounted for) was developed to determine how the measurements made by each of the various instruments relates to visual range and to examine other parameters that might be used to quantify visibility degradation. The model examines the effect of:

(1) Absorption,

(2) The vertical distribution of scattering coefficient,

(3) Curved earth,

(4) Variation in observation angle,

(5) Variation in the zenith angle,

(6) Chromatic object,

(7) Sun angle.

Model calculations were carried out for a target distance of 50 km and for aerosol scattering coefficients of 0.0, 0.02, 0.04, and 0.06 km^{-1}. The wavelength was varied from 400 to 700 nm.

Figure 1 shows the geometry for the calculation. An observer measures, under a cloudless sky, the apparent sky and target radiance of a mountain 50 km distant. If the earth were flat and the atmosphere horizontally homogeneous the measured apparent sky and target radiance would allow a calculation of the furthest distance the observer could see a similar target. The implication being that the sky radiance at the target $_sN_t$ and the observer $_sN_o$ are equal (see assumption 6).

Figure 1 shows the effect of earth curvature and illustrates that the observer would be looking through a vertically stratified atmosphere if he were to reach the limit of observing distance. In fact, if the visual range were 355 km the target, due to earth curvature, would have to be 10 km high; a very high mountain indeed!

Figure 2, a graph of visual range versus wavelength, shows a family of curves that would result from the calculation of visual range using data gathered by an integrating nephelometer, (□), telephotometer (*) and actual visual range (0), for atmosphere with different amounts of scattering. Since the integrating nephelometer is a point measurement of scattering coefficient similar results would occur from similar measurements. The telephotometer is a measurement at the observation point of the difference between sky and apparent target radiance. It assumes that the sky radiance at the target and the observation point are the same. Actual visual range allows for the differences between sky radiance at the object and at the observation point which results from increased target height required to maintain a constant observation angle at a longer viewing distance.

For an aerosol scattering coefficient of zero, Figure 2 shows telephotometer and nephelometer type measurements yielding similar results at 405 and 436 nm: both instruments predict visual ranges somewhat lower than the real visual range. However, at 546 nm the real visual range is below the visual range predicted by either a telephotometer or nephelometer. This descrepency is amplified as the wavelength is increased by 700 nm. Similar calculations were carried out for aerosol scattering coefficients varying from 0.02 to 0.06 km^{-1} in 0.02 km^{-1} increments. At 406 and 436 nm, all measurements agree to within 10%. However, at large wavelengths, both scattering and elephotometer type measurements consistently yield a visual range that is less than "real". Both instruments sample atmosphere which is located near the earth surface while in reality (see Figure 1) visual ranges of over 200 km require the observer to view objects which extend well above the ground and above the mixing layer. When the "view" can extend above the mixing layer, measurements within the mixing layer tend to under estimate the real visual range.

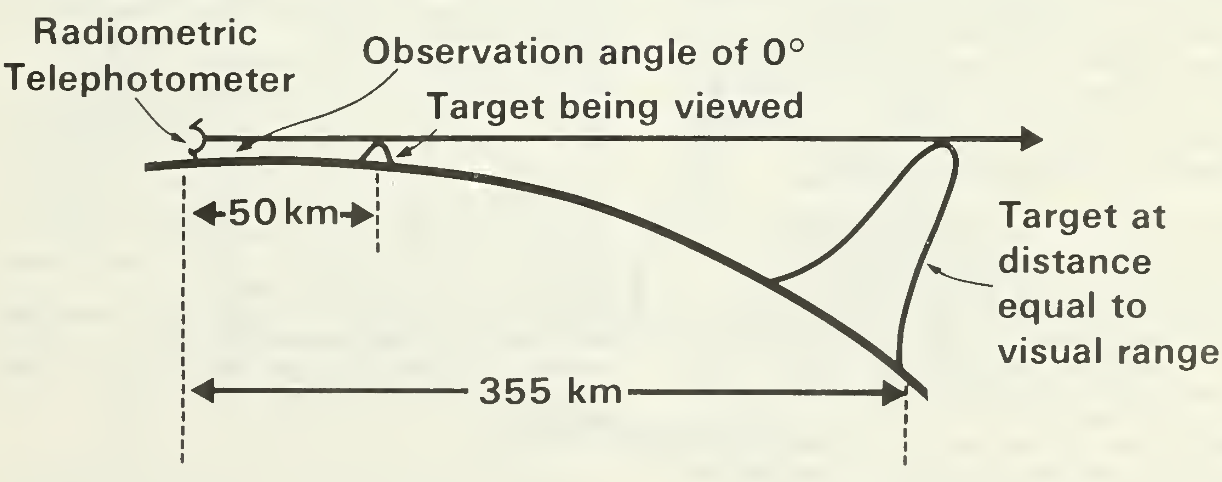

Figure 1.--Geometry of visual range.

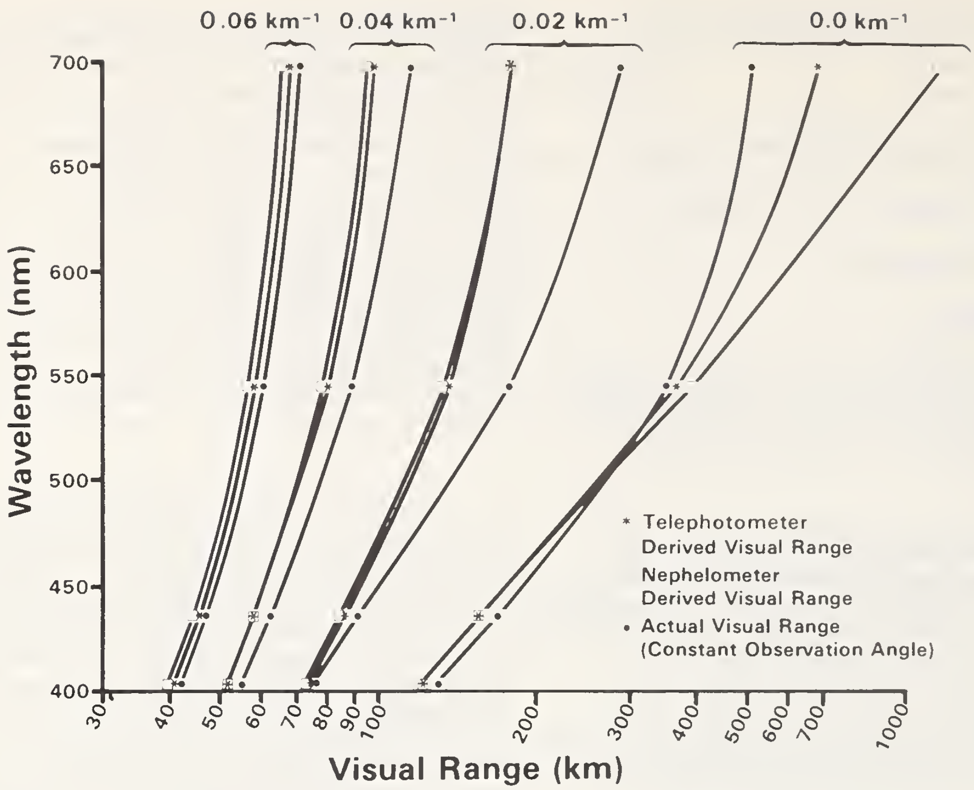

Figure 2.--Visual range with a 0^{o} observation angle as determined by telephotometer, nephelometer, and calculated as described in the text, plotted as a function of wave numbers over the visual spectrum assuming different atmospheric aerosol loadings.

If there were nitrogen dioxide (NO_2) present, the discrepancy between visual range derived from a scattering measurement and actual visual range would increase because of absorption. Under worst conditions an NO_2 concentration of 0.5 ppm might be expected at about 1 km from a power plant like the Navajo Generating Station. Robinson (1977) indicates that NO_2 has an attenuation coefficient of 0.3 ppm^{-1} km^{-1} at 550 nm. If a 0.25 km plume width were assumed, 0.5 ppm NO_2 would translate into a 284 km visual range over a sight path of 10 km at 2140 m altitude. A scattering coefficient type measurement would yield approximately a 400 km visual range.

All targets are not viewed horizontally. Many vistas require an inclined view. An observer may view a target or object at some distance and ask himself "How far can I back away from the object and still see it." In this case (constant target height) the observation angle will necessarily decrease as the observer backs away from the object. An alternative way for the observer to address the problem is to ask "How far could I see successively distant targets maintaining the same observation angle." This would require that each successively distant target be greater in altitude than the previous one. Or the observer might facetiously require the target to back away from him and grow simultaneously in such a way that he maintain a constant observation angle. Even if the observer views an object (0^{o} observation angle), earth curvature will still require that each successively distant target be greater in altitude than the previous (see Figure 1). To observe the effect that angle of observation has on visibility, the previous calculations were carried out for a constant observation angle of 5^{o}. Figure 3 shows the results of these calculations. For an aerosol scattering coefficient of zero, calculations show that at short wavelengths (blue part of the color spectrum) a point scattering type measurement (◘) will yield a visual range, while longer wavelengths indicated visual range may be as much as 300% higher than the real visual range. Real visual range and the visual range calculated from a telephotometer type measurement are approximately the same.

At increased aerosol loading scattering coefficient = 0.04 km^{-1} point scattering measurements yield visual ranges that are

significantly lower than real visual ranges (≈60%) while a telephotometer indicates a visual range of about 20% lower than real. This effect is primarily due to a curved earth and viewing angles other than horizontal that cause a point measurement to sample air that is not at all representative of air in the observation path. While a telephotometer "measures" air samples over a longer path, (typically 50 to 100 km) and thus gives a closer representation of true visual range, it still does not sample air over a path length that is equal to the visual range.

In order for the telephotometer-derived visual range to equal real visual range, the sky radiance at the object and observation point must be equal and the average attenuation coefficient between the observer and target must be the same as that between the observer and a distance equal to the visual range. Viewing an object at some observation angle greater than 0^{o} implies that the sight path extends up through an atmosphere. Typically the scattering coefficient decreases exponentially as elevation is increased. As a result the apparent attenuation coefficient between the observer and an object at V_r is less than over a shorter path and the sky radiation at the object will be substantially less than the sky radiance at the observer (flat earth cannot be assumed). Comparison of Figures 2 and 3 shows that this effect is greatly amplified as observation angle is increased; additionally since ${}_{s}N_{t}$ at longer wavelengths tends to be dependent on molecular and aerosol scattering above the mixing layer, a telephotometer measurement in the red portion of the spectrum might be used to monitor aerosol changes that take place in the upper layers of the troposphere as well as within the stratosphere.

Variation in the vertical distribution of aerosol concentrations has much the same effect as a variation in observation angle. Variation in vertical distribution of aerosol concentration and in observation angle effectively change the aerosol scattering coefficient through which an observer must

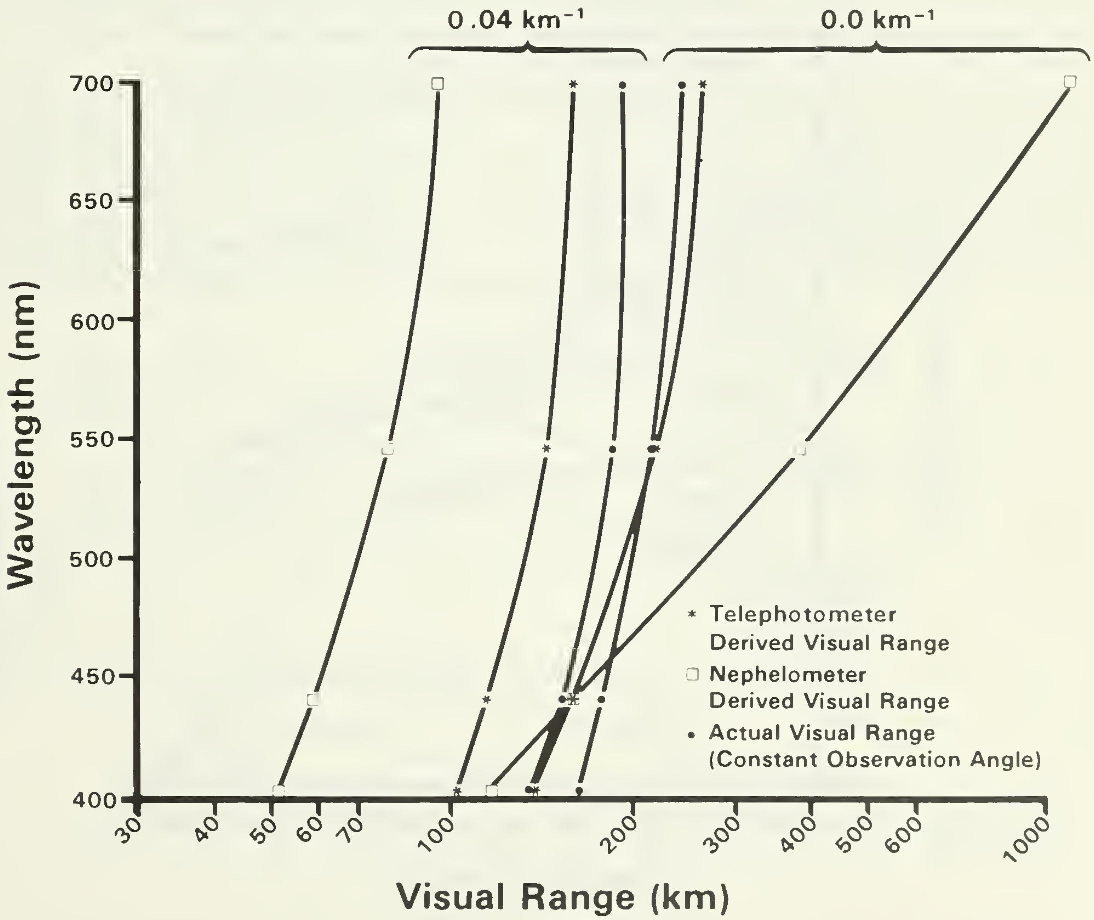

Figure 3.--Same as Figure 2 but illustrating the effect of a 5^{o} constant observation angle.

view an object. The model calculations show that variation of aerosol content above the mixing layer has little influence on real or telephotometer-derived visual range when measured at 400-450 nm at an observation angle near 0^{o}.

PHOTOPIC VISUAL RANGE

All of the above calculations relate to "monochromatic visibility" of a black target. In reality an observer views a distant vista with his/her eye. Consequently, a representative visual range can be found by comparing object and sky radiance measured at various wavelengths, with the spectral sensitivity of the human eye. This allows for a calculation of "photopic visual range." Calculations of the photopic of visual range were made for both constant target height and constant observation angle cases.

Figure 4 is a graph of photopic visual range, as determined by various instruments, as a function of observation angle.------- represents the visual range predicted by a ground-based point scattering coefficient measurement; while —□—is the visual range predicted by a telephotometer measurement of apparent object and sky radiance at 50 km. • and ⊛ are the real visual range for constant observation angle and constant target height respectively.

These four curves are plotted for aerosol scattering coefficients of 0.0, 0.02, and 0.06 km^{-1}. Figure 4 emphasizes the difference between visual range as determined by nephelometer and telephotometer measurements, as well as their relationship to real visual ranges. Discrepancies are amplified as the observation angle is increased. Reasons for these discrepancies were discussed in relationship

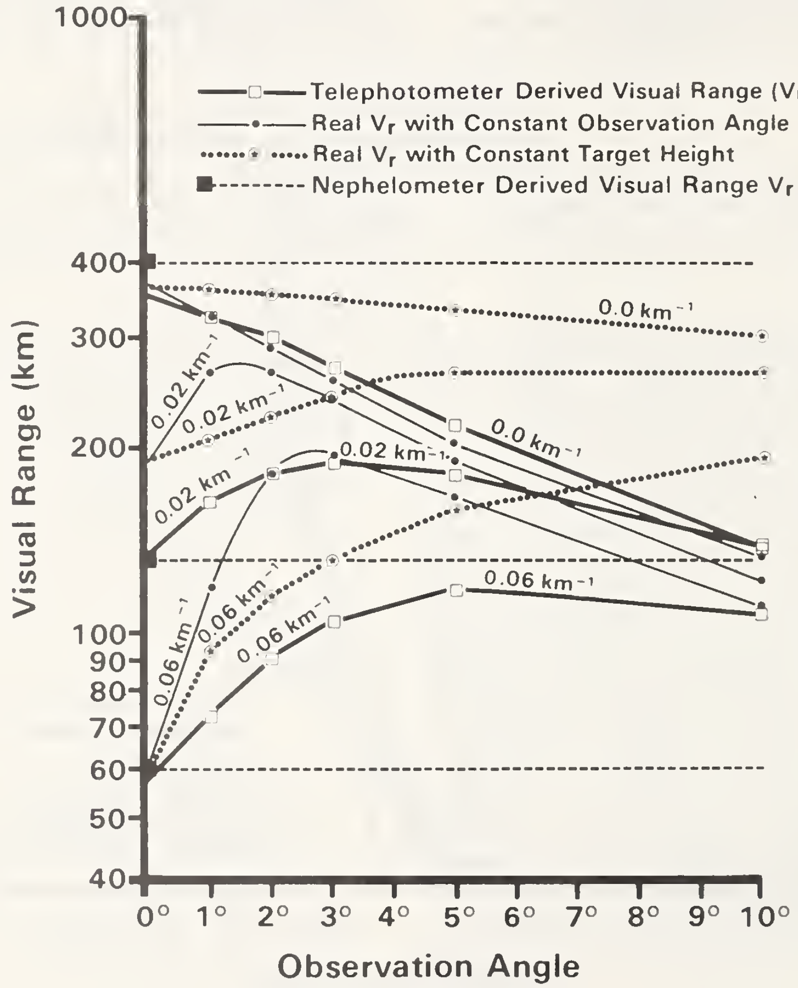

Figure 4.--Effect of observation angle, aerosol scattering coefficient, calculation procedure, and measuring instrument on visual range.

to Figures 2 and 3. Figure 4 shows that at zero observation angle a contrast type measurement yields, in most cases, a visual range comparable to the real visual range. However, for angles of observation between 1° and 4°, photometer measurements compare most favorably with the constant target height interpretation while at large angles of observation the photometer-derived visual ranges compare best with a constant observation angle calculation. Nephelometer measurements compare favorably to real range at zero observation angle. However, at observation angles greater than zero, errors approach 75%.

In any case, it is not clear whether targets should grow or observers recede. It seems evident that there is not one measurement or combination of measurements that will allow for a calculation of true visual range. A visual range calculated from an observation made at 5° will not be the same as one made from an observation at 0° even though the measurement was made at the same location through the same atmosphere. Whether the measurement is made by a nephelometer, transmissometer or telephotometer, the true visual range will have to be approximated by a model.

There are however, two other variables that can be directly monitored and are related to visibility namely the scattering coefficient, and the apparent target contrast. Apparent target contrast is the contrast transmittance if the inherent target contrast is known or measured. Contrast and contrast change relate directly to what the eye "sees."

Figure 5, a plot of contrast change (resulting from an increase of 0.01 km^{-1} in attenuation coefficient) as a function of target distance for initial attenuation coefficients of 0.01, 0.03, 0.05 and 0.1 km^{-1}, shows that change in contrast is dependent on target distance as well as on the "pollution level" of the atmosphere. In pristine atmospheres distant targets (50-120 km) are much more sensitive to aerosol attenuation coefficient changes than are targets located 10-20 km away. For example, in clean atmospheres an increase in the attenuation coefficient of 0.01 km^{-1} will result in a contrast change of 0.25 for a target that is 50-120 km away from the observation point while the same variation in attenuation coefficient for a target at 10 km results in a contrast change of 0.1. For targets at the same distances, Figure 5 shows that contrast change, as a function of increased aerosol scattering attenuation is greater in clean than in dirty atmospheres.

Equal changes in aerosol scattering are not reflected in equal changes in contrast or contrast transmittance. Since contrast and contrast change reflects what the eye sees, apparent target contrast is one parameter that will effectively characterize visibility. Apparent target contrast is site specific, but then each site is unique and may require evaluation of its scenic quality based on its unique features. However, apparent target contrast can be used to calculate unit contrast transmittance (UCT), a parameter that can be used to intercompare measurements from various sites. UCT can be determined with the help of equation (2);

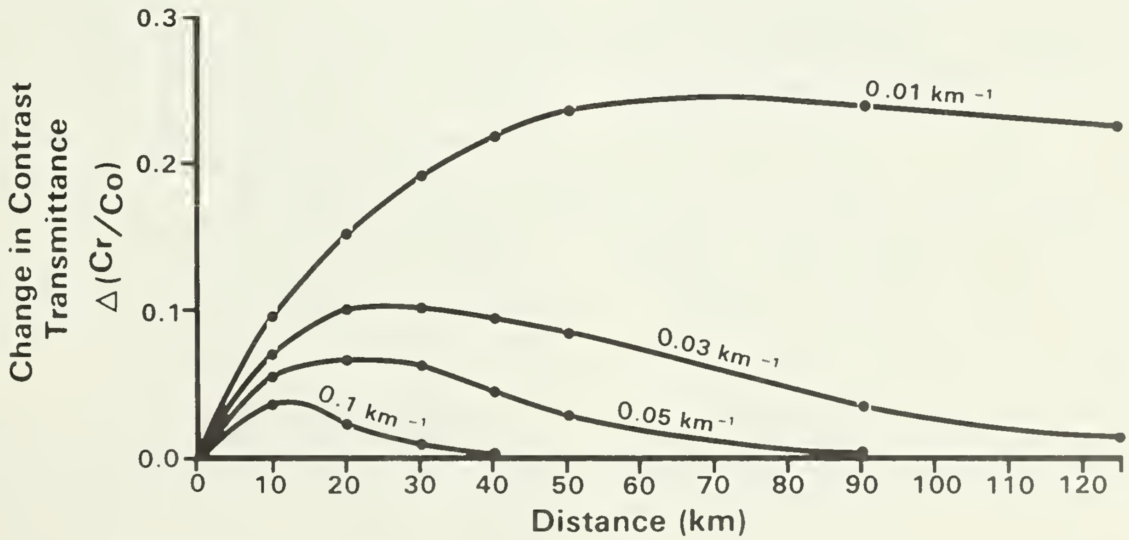

Figure 5.--Contrast change as a function of target distance and aerosol scattering coefficient.

$$C_r = C_o \; T_{ray} \; T_a. \qquad (2)$$

C_r is the apparent target contrast at a distance r while C_o is inherent contrast (contrast at an observer distance equal to zero). T_{ray} and T_a are the contrast transmittance of the rayleigh and non-rayleigh component of an atmosphere between an observer and a target located at distance r.

If the atmosphere is extremely clean, T_a=1, and equation (2) reduces to

$$C_{r,Ray} = C_o \; T_{ray} \qquad (3)$$

where $C_{r, Ray}$ is the apparent target contrast in a near Rayleigh atmosphere. Dividing equation (2) by equation (3) yields:

$$C_r/C_{r,Ray} = T_a. \qquad (4)$$

Using apparent target contrast measured on very clean days ($C_{r,Ray}$) in conjunction with measured apparent target contrast on any other day will allow for the calculation of T_a, the contrast transmittance of non-raleigh attenuation between an observer and some target. T_a raised to 1/r power, $(T_a)^{1/r}$, is then, the contrast transmittance of non-raleigh attenuation for one unit of length (UCT).

Apparent target contrast can also be transformed into visual range. However, a calculation of visual range requires a knowledge of C_o, a near zero observation angle, and an atmospheric aerosol scattering coefficient large enough to assume the sky radiance at the target and observer are the same. In addition, visual range would have to be adjusted to sea level to allow intercomparison of sites that are located at various altitudes. On the other hand UCT, calculated using equation 4, is independent of altitude, as well as inherent contrast C_o. UCT appears to be a good candidate for characterization of visibility.

This analysis has neglected possible horizontal inhomogeneities. There are many vistas that require an observer to look over or through valleys and canyons. These "pollution corridors" funnel or channel particulates in such a way as to effect the ability of an observer to "see" vistas behind the corridor while landscapes in front will remain "clear." Mesa Verde National Park is an excellent example. On many days part of the Chuska Mountains 50 km away cannot be seen from Mesa Verde. On these same days, measurements of the scattering coefficient at Mesa Verde have indicated a visual range in excess of 200 km.

An additional consideration that is not addressed by the above model calculations is ground reflectance. The volume scattering function in conjunction with ground reflectance plays an important role in determining how much additional light is scattered toward the observer. It is possible to have a varying volume scattering function even though the scattering coefficient remains unchanged. This would translate into a real change in contrast transmittance or in visual range even though point measurements of the scattering coefficient indicate a constant contrast transmittance/ visual range. An example of where ground reflectance and volume scattering probably plays a major role in determining visual range is in the Grand Canyon. The Grand Canyon has many bright colored rock faces and cliffs which contribute to the illumination of the sight path. Contrast readings in the Grand Canyon are always lower in the red portion of the spectrum (indicating illumination of sight paths by red light) than would be expected. Under such conditions, ground reflectance and volume scattering function combine to reduce contrast and thus visual range.

An increase of the scattering coefficient in areas such as the Grand Canyon will affect visibility to a much greater degree than the same scattering coefficient increase would in an area where the ground is covered by forest. A given increase in scattering coefficient at one location may be visually perceptible while the same increase in another location may not.

CHROMATIC (COLORED) TARGETS

The preceding discussion was only applicable to black or achromatic targets, those with an inherent contrast equal to minus one or constant contrast for all wavelengths. Of equal importance is the visibility of colored targets. It is possible to calculate monochromatic visual ranges for any of an infinite set of chromatic targets. A colored target with an inherent contrast of three may be seen clearly for hundreds of kilometers while a black target would be less distinct. Additionally, if inherent contrast of a chromatic target is approximated or measured, it is possible to calculate an apparent attenuation coefficient that can be used to approximate the visual range of a black object in the same atmospheric conditions.

However, a human observer does not view a vista under monochromatic lighting conditions nor does his eye respond to one wavelength of light. A calculation of the visual range of a chromatic target at only one color does not adequately address the perceived change that a human observer would experience under changing pollutant concentrations. The eye

responds to differences in chromaticity as well as to differences in luminance, and consequently it may also be necessary to characterize color change. Color and color changes can be quantitatively represented on what is referred to as a chromaticity diagram (see Figure 6). Colorimetric purity and dominant wavelength can be calculated. Purity is a measure of how much white light is mixed with a pure color while dominant wavelength may be thought of as the most intense color of the many colors that are reflected from any object.

Figure 7 indicates the change in the chromaticity of a red target as a function of distance and aerosol scattering coefficient. Figure 7 is an enlarged section of the central portion of a chromaticity diagram. The X chromaticity coordinate extends from 0.3 to 0.5 while the Y coordinate extends from 0.30 to 0.39. O represents the "inherent" chromaticity coordinates of the hypothetical chromatic target as well as the chromaticity coordinates of illuminant C. The o, *, ◻, and • represent the apparent chromaticity coordinates for a chromatic target at various distances for aerosol scattering coefficients of 0.0, 0.02, 0.04, and 0.06 km^{-1} at 550 nm.

Alteration of target as a function of distance for different aerosol scattering coefficients is of interest. Figure 7 shows that in rayleigh limit as an observer backs away from a target (reddish in this case), the inherent color becomes "washed out," and its dominant wavelength shifts to longer wavelengths or becomes "more red." On the other hand, for increasing aerosol loads there is less of a shift in dominant wavelengths as an observer backs away from the target. However, the target becomes gray or "hazy" much faster as the distance is increased.

It is interesting to note the effect that equal incremental changes of the aerosol scattering coefficient have on color at various observation distances. At 10 kilometers a change in the aerosol scattering coefficient from 0.0 to 0.02 km^{-1} is not perceptible

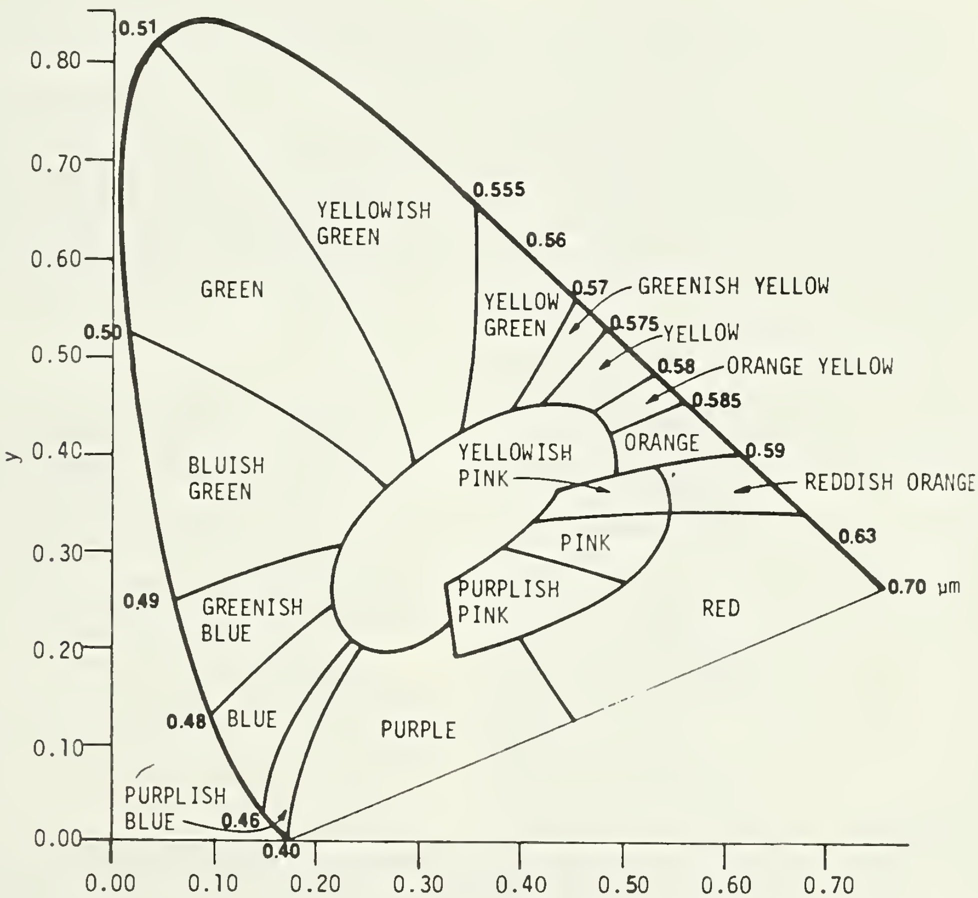

Figure 6.--Chromaticity diagram which maps color into a two-dimensional surface as explained in the text.

while a change from 0.04 to 0.06 km^{-1} is much more than just perceptible. On the other hand, a change in aerosol scattering coefficients from 0.0 to 0.02 km^{-1} at 50 and 100 km is much more than perceptible while a change from 0.04 to 0.06 km^{-1} is less perceptible at either 50 or 100 km than at 10 km. Stated differently, Figure 7 shows that at 100 km an incremental change in the aerosol scattering coefficient is more perceptible in a clean atmosphere than a dirty atmosphere. For short observation distances, just the opposite is true. This analysis shows the importance of observation distance in determining the effect of varying aerosol loads.

Figure 8 is a similar diagram showing expected color changes for a black target (approximated by a tree covered mountain) as a function of target distance as well as particulate concentrations (scattering coefficient). In this case o, *, □ and ● represent the color coordinates at various distances for aerosol scattering coefficients of 0.0, 0.02, 0.04, and 0.06 km^{-1} at 500 nm. Trends is Figures 7 and 8 are similar in that the target, whether black or red, becomes "washed out" as distance and atmospheric particulate load are increased. However, there are important differences. For clean atmospheres black targets show significantly greater color sensitivity to increased particulate loadings than do colored or chromatic objects. Additionally, a black object viewed in a clean atmosphere will experience a large color change at short distances while chromaticity changes of a red target, under similar atmospheric conditions, is not detectable.

MacAdam (1942, 1943) and others have developed a set of data corresponding to threshold chromaticity differences, i.e., changes in chromaticity coordinates that correspond to just barely perceivable changes of color. The work of MacAdam also shows that the eye's ability to perceive color change is not the same for all locations on the chromaticity diagram. However, chromaticity coordinates can be transformed to a uniform chromaticity scale (1943) that will allow for the characterization of a change in color of chromatic targets that is independent of their perceived color. Consequently a visibility standard could be expressed in terms of a color change that is independent of target on vista chromaticity.

A telephotometer, measuring target radiance at a number of wavelengths, can be used to directly determine the chromaticity coordinates of the target. In addition, a determination of the chromaticity coordinates can be used to "generate" a picture of the vista on the day the measurement was made.

It should be re-emphasized that the model used to determine the chromaticity coordinates as a function of aerosol scattering neglected ground reflectance. If the ground were colored or white, all the above discussed effects would be enhanced. It would take even a smaller increment in aerosol scattering to induce a perceptible change in color. Also absorption of gases, other than ozone, has been neglected. Color alterations resulting from variations of NO_2 concentrations are significant and can also be characterized by a chromaticity change.

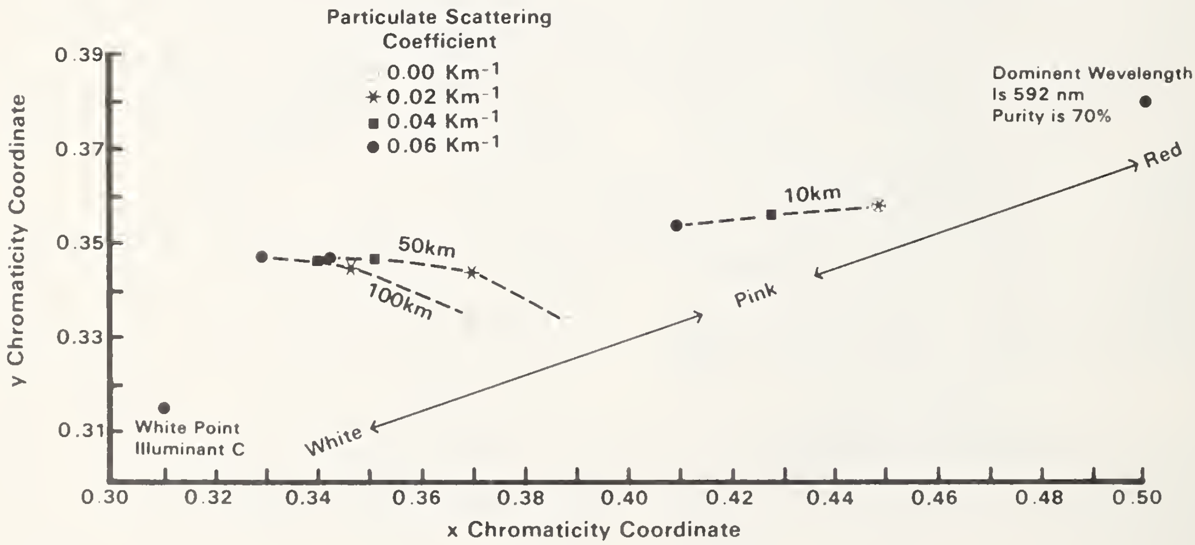

Figure 7.--Change in chromaticity of a red target as a function of distance of observer from target and aerosol scattering coefficient.

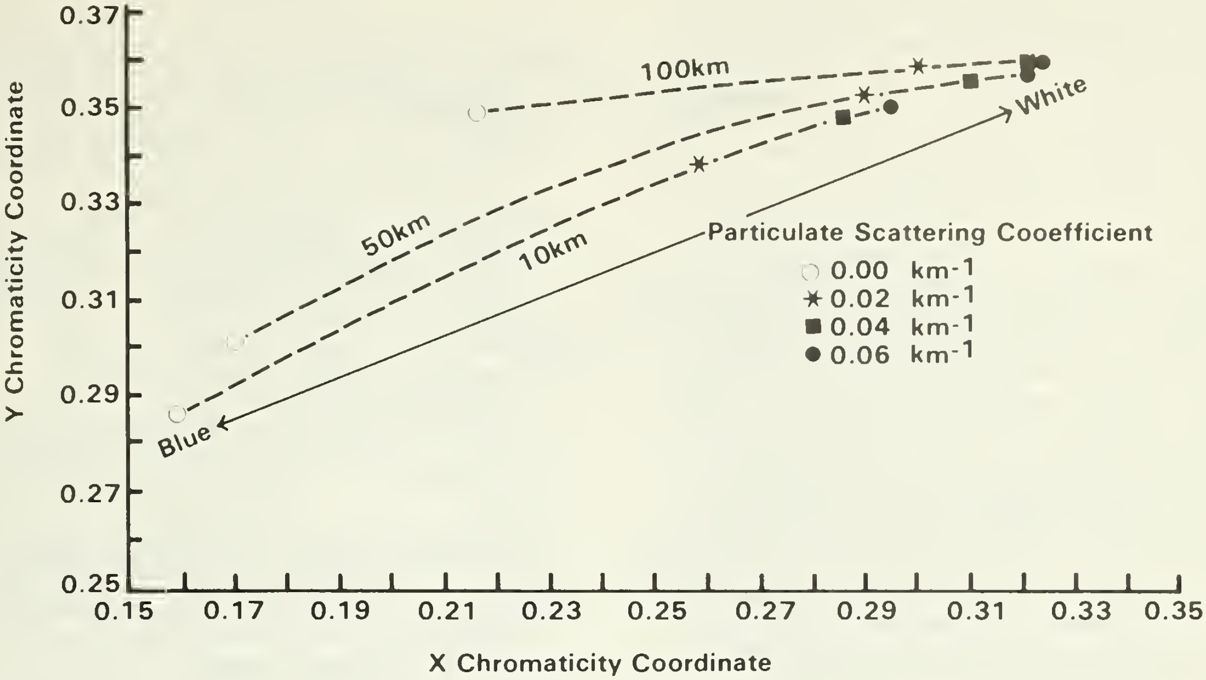

Figure 8.--Change in chromaticity of a black target as a function of distance of observer from target and aerosol scattering coefficient.

CONCLUSION

The question under consideration is: What is the best way to measure and characterize visibility? Classically "visibility" implies to most workers in the field a determination of how far (the visual range) an observer can see a specified target viewed against some background.

In order to calculate visual range one must know or calculate the spatial variation of the path radiance, apparent target radiance, sky radiance at the target and at the observation point, and spatial variation of the attenuation coefficient. If the target is chromatic, a determination of the inherent target radiance is also necessary. If the path function, ground reflectance and volume scattering function were known for all points on the ground or within the atmosphere, these optical parameters could be calculated for achromatic or chromatic targets. Needless to say it is impossible to measure the path function and volume scattering function for every point in the atmosphere; it is even economically prohibitive to fly aircraft through the atmosphere on a semi-routine basis in an effort to approximate these functions at various altitudes. Continuous measurements are therefore restricted to ground-based instrumentation.

From the discussion it should be apparent that from a ground-based measurement, it is probably difficult if not impossible to make one measurement or even a set of measurements that would allow a direct determination or even a set of measurements that would allow a direct determination or even calculation of a real visual range. In fact, visual range does not relate well to what a person experiences upon visiting pristine areas. Upon viewing a distant vista, a person does not ask himself, "How far do I have to back away from that mountain before it disappears?" More likely a person will comment on how hazy the vista looks or how clear it appears, the brightness of colors in the vista or the brownish or bluish color of the intervening atmosphere.

Consequently, rather than trying to document visual range, a better way to characterize visibility may be to either document apparent target contrast (contrast transmittance of the atmosphere between some vista and observing point if the inherent contrast of the target is known) or document temporal changes in color of selected vistas. It is possible to quantify color/color change on what is known as the uniform chromaticity scale. A visibility standard could be specified in terms of not allowing a specified change in either of these parameters. In each area of interest, one could monitor apparent target contrast or color in much the same way that sulfur dioxide concentrations or total suspended particulates are monitored. A baseline "visibility" is established and standards are written in terms of incremental change from this baseline.

There are, however, important differences between these two parameters. Apparent target contrast is not very dependent on sun angle, while the color change of a distant vista is. Consequently, contrast data can be intercompared without critical regard for sun angle: morning versus afternoon, or winter versus summer. On the other hand, contrast ignores the effect that sun angle has on an observer's ability to see detail or inherent color in a given vista. As sun approaches angles that are conducive to forward scattering, the path radiance (sky light contribution to apparent object radiance) will dominate the inherent radiance of the object and detail will tend to be "washed out." Apparent target contrast will not have changed while the ability to "see" the object has degraded significantly. It is under these conditions that a small change in aerosol concentration will cause a large change in the ability to see an object. A "color measurement" would be sensitive to changes due to these small amounts of aerosol concentration. A measurement of color that is sensitive to sun angle would require a careful documentation of the solar zenith.

Chromaticity and apparent target contrast have the advantage of being directly monitorable. When a standard is being established, a variable should be chosen that represents that quality of the environment to be protected, and the variable should be directly monitored rather than calculated from a model. Visual range is a parameter that would require modeling in the sense that it cannot be determined by one or a set of measurements but rather is calculated from a model containing several restrictive assumptions. However, both chromaticity and apparent target contrast are site-specific measurements. When intercomparisons between sites are made, it will be necessary to "normalize" contrast data by converting to unit contrast transmittance (the ability of the atmosphere to transmit contrast over one unit of length), a parameter that is not site-specific. Because of its familiarity, visual range remains a useful concept, when its limitations are realized, for the transmittal of monitoring results to the general public.

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Analysis of Scenic Degradation Caused by Air Pollution[1]

Douglas A. Latimer[2]

Abstract.--This paper describes a current study to determine whether quantitative relationships exist between human judgments of scenic and visual air quality and physical parameters that quantify visibility impairment, such as visual range, contrast, chromaticity, and ΔE. Other needed research is also described.

INTRODUCTION

Through the Clean Air Act Amendments of 1977, Congress broadened the scope of existing air quality legislation to include a new objective: the protection of visibility in particularly scenic areas such as national parks, wilderness areas, forests, and recreation areas (federal Class I areas). Congress was particularly concerned that existing coal-fired power plants in the Southwest might be causing haze and atmospheric discoloration in several national parks and that anticipated future energy development would cause further impairment of visibility and degradation of scenic quality. Consequently, the Environmental Protection Agency was ordered to develop both long- and short-term strategies to remedy existing visibility impairment and prevent future impairment in Class I areas. In addition, Congress required that federal land managers take "an affirmative responsibility to protect the air quality related values (including visibility)" in Class I areas. The EPA and federal land managers, as well as the states, were given the authority to deny construction permits for any proposed source expected to have an adverse impact on visibility in a Class I area. These visibility regulations are likely to have profound effects on the development of energy resources in the western United States because of the large number of Class I areas located there.

To assist in its national goal to prevent visibility impairment, Congress required the EPA to study and make recommendations regarding:

> Methods of measuring, characterizing, and quantifying existing visibility impairment.

> Modeling techniques for determining the impacts of present and future man-made air pollution on visibility in Class I areas.

> Methods to prevent such impairment.

These studies are now nearly complete. EPA's Environmental Monitoring and Support Laboratory in Las Vegas has developed techniques for documenting and quantifying existing visibility impairment. Under contract to the EPA, Systems Applications, Incorporated (SAI) has developed computer simulation models to estimate the impact of current pollutant emissions and to predict the impact of future emissions on visual range and atmospheric discoloration (Latimer et al., 1978).

Both the measurement and modeling techniques provide quantitative results that are, at present, not correlated with the essentially subjective, aesthetic human judgments of visibility quality in Class I areas. Qualitative judgments of visibility impairment, such as the terms "clear," "hazy," and "discolored," are not useful for regulatory purposes. The quantitative approach is both necessary and desirable since well-understood physical phenomena are responsible for the spectral light intensities that convey to the human observer the appearance of either spectacular scenery and clear blue skies or impaired visibility and discolored haze. But quantitative specifications of visibility are meaningless, esoteric terms unless they can be related to human ratings of visibility quality. Without reliable, valid, useful correlations, decision-makers will not be able to use effectively the information provided by measurements and models.

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[1] Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

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In the development of models for predicting visibility impairment, we adopted quantitative definitions of visibility impairment that are directly related to what an observer sees, namely, the spectral radiance distribution for specific lines of sight [$I(\lambda)$]. The models calculate radiance at various wavelengths from the principles of radiative transfer associated with the viewing of specific objects (e.g., a clear sky, a white cloud, and a distant mountain) through an atmosphere containing concentrations (not necessarily uniform) of aerosol and NO_2. To develop relationships between the strictly physical values of spectral radiance and what a human perceives, one must first apply to radiance a weighting factor (the psychophysical response characteristics of the different light sensors of the human eye) to obtain luminance, which is related to the perceived brightness, and to obtain chromaticity, which defines the hue and saturation of the perceived color.

The development of relationships among quantitative specifications is only an intermediate goal in relating human perceptions to objective parameters of visibility: There remains the problem of quantifying human judgments of visibility quality. The brightness and color of an individual element (line of sight) in a scene can be evaluated by an observer or measured, but it is not at all clear that human judgments of a whole landscape can be defined by its elements. Research in gestalt psychology suggests that the components of a perceptual "whole" may not adequately explain the "whole" into which they are assembled--in fact, interactions among components may at times be more important than the components themselves (Arthur, Daniel, and Boster, 1977). To evaluate human judgments of visual air quality, one must present examples of visibility impairment to one or more human observers for rating. From those ratings a perceived environmental quality index (PEQI) can be derived to relate human judgments to quantitative specifications of visibility impairment.

QUANTIFYING HUMAN JUDGMENTS OF VISIBILITY IMPAIRMENT

The purpose of this paper is to outline a study currently underway at SAI, funded by the American Petroleum Institute, to determine whether quantitative parameters can be related to human judgments of visibility impairment and to identify appropriate definitions, surrogate measures, and indices of visibility impairment.

A valid index of visibility impairment must be indicative of human judgments of visual impact or scenic degradation. Visual range by itself, for example, may not be a valid index because (1) it is dependent on the given line of sight owing to inhomogeneities in aerosol concentration, (2) significant plume blight or atmospheric discoloration could occur with good visual range, and (3) in certain situations reduced visual range may be correlated with increased scenic beauty. Fog lying along a sea coast, clouds touching a mountain peak, and a sunset viewed through haze are all instances of scenic beauty enhanced by reduced visual range. Where scenic "texture" or visual clarity is an important value, however, visual range may be a valid index, and the "desirable" visual range may be great. The above examples suggest that a degree of visibility impairment that is significant in one area or time period may not be significant in others; for example, increased haziness may be far more perceptible and objectionable in the Grand Canyon than in the Smoky Mountains or a dense forest.

PHYSICAL, PHYSIOLOGICAL, PSYCHOLOGICAL, AND SOCIAL ASPECTS

As noted above, visibility impairment and scenic quality as judged through human perception must ultimately be subjective. It is useful to analyze the nature of visibility impairment and scenic quality with a conceptual structure starting with the scene viewed and ending with human judgment. The elements in that judgment are as follows:

> The physical environment (specific features such as hills and mountains, water bodies, vegetation, buildings, and clouds).

> The atmosphere through which the environment is viewed.

> The human eye-brain system, with its light receptors (rods and color sensitive cones).

> The characteristics of the observer. The different values, expectations, and attitudes of different people and social groups may have a significant effect on their judgments.

With this classification, we can study the problem in an objective manner. We can identify attributes of the physical environment that contribute to scenic quality, for example, the characteristics of the terrain (flat, hilly, or mountainous); the spatial frequency of various objects; the spectral reflectance (inherent color) of rocks, soil, water bodies, vegetation, roads, and buildings; the solar zenith angle;

and the occurrence of cloud cover. The intervening atmosphere can be characterized by the concentrations of trace gases and the concentrations, size distributions, and light scattering and absorption coefficients of aerosols. The human perception of a scene, of course, depends on the location of the observer with respect to that scene. More importantly, however, the reactions of human observers to a given scene depend on their reasons for viewing the scene and on their general attitudes, values, beliefs, and social orientations.

RESEARCH

The approach that we are taking in our research is to document several scenic vistas under a variety of atmospheric conditions with color photography and multiwavelength telephotometry and nephelometry. Color slides of the scenes will be presented to observers for ratings of visual air quality and, in separate tests, of scenic quality. These ratings and quantitative specifications of the scenes based on the telephotometer and nephelometer measurements will be used in an attempt to determine the effects of characteristics of the scene and the intervening atmosphere on human judgments of scenic and visual air quality. It may be possible to use an index of scenic beauty such as that developed by Daniel and Boster (1976), in conjunction with an index of visual air quality based on the quantitative parameters developed by Latimer et al. (1978), to determine definitions of visibility impairment that are applicable to a variety of areas. Some combination of quantitative specifications may be found that correlates well with human judgments of visual or scenic quality.

Figure 1 illustrates in schematic form the conceptual elements of our approach. Photographs of selected scenic vistas will be taken under a range of air quality conditions. When each photograph is taken, the spectral radiance of various elements of the vista will be measured with a multiwavelength telephotometer and the scattering coefficient will be measured with a nephelometer. Psychophysical parameters that characterize visibility impairment will be computed from those measurements. Important psychophysical parameters include:

> Contrast of viewed objects (indicative of haziness and loss of clarity in form, line, and texture).

> Contrast of haze layers (indicative of the perceptibility of the air pollution itself).

> Luminance (overall perceived brightness).

> Chromaticity coordinates (indicative of color hue and saturation).

> ΔE (proportional to overall perceptibility of changes in brightness and color).

Photographs and telephotometer measurements of selected vistas will be taken under a variety of conditions in order to provide several examples of different haze conditions, lighting, and cloud cover. Color slides and color prints will be presented to selected panels of observers representative of various segments of the public, such as student, civic, business, church, and environmental groups. Some panels will be asked to judge visual air quality; others will be asked to judge scenic quality. Observers will record their judgments of visual air quality or scenic quality on a scale from 1 (very low quality) to 10 (very high quality). Ratings will then be individually transformed to yield standardized interval scales of perceived quality. Psychophysical scaling procedures also described by Daniel and Boster (1976) will be employed to ensure direct comparability of judgment indices across the different observer panels. These indices will be used in subsequent analyses relating the psychophysical parameters (contrast, chromaticity, ΔE, etc.) to the public judgment indices, using such statistical techniques as multiple regression and factor analysis. With the psychophysical parameters as independent variables, separate equations will be derived, where possible, to predict human judgments of scenic and visual air quality. Thus, means may be established for estimating human responses to a wide range of visibility impairment and scenic conditions.

VISIBILITY RESEARCH NEEDS WITHIN THE REGULATORY CONTEXT

The research just described covers only one aspect of a problem that warrants further study. Further work is needed to implement, on a sound technical basis, Congress's goal to restore and protect visibility in scenic areas and to balance visibility and air quality goals with other national goals, such as energy self-sufficiency.

Further work will be required in the following areas:

> Strict definition of visibility impairment to ensure proper quantification and measurement.

> Measurement of existing visibility impairment and associated air pollution.

> Distinction between natural and man-made visibility impairment.

> Identification of specific source and air pollutant contributions to visibility impairment.

> Further refinement and validation of models to predict the impact of new and existing sources on visibility.

> Establishment of criteria of acceptability of visibility impairment.

Figure 2, a schematic logic diagram showing the regulatory context of visibility restoration and protections, is helpful in putting these research needs in perspective. The regulatory structure shown in this figure is, in effect, a feedback mechanism whereby existing and future emissions are managed in such a way that visibility is not impaired and scenery is not degraded in Class I areas.

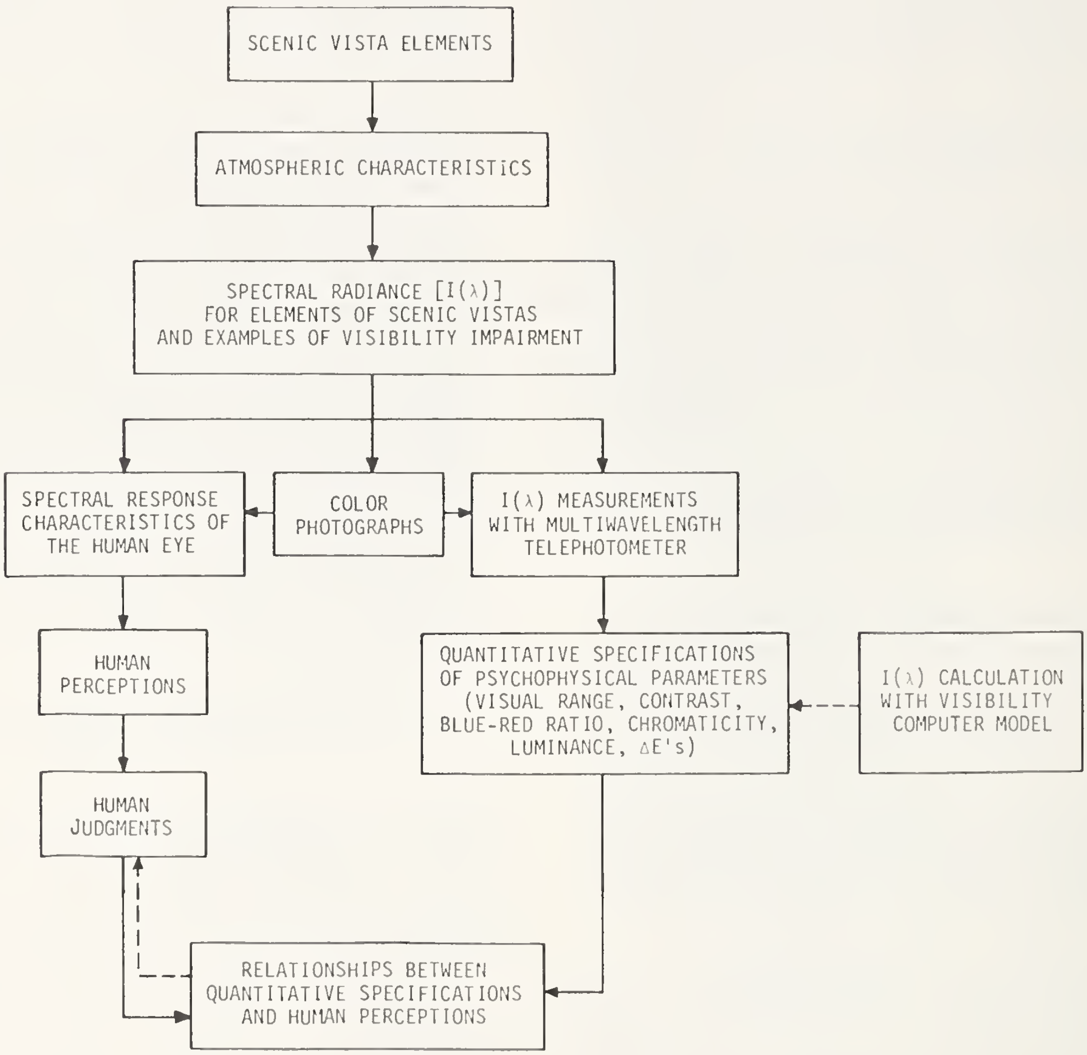

Figure 1.--Schematic diagram of the research approach to the quantification of human judgments of visibility impairment.

The promulgation of regulations (shown by the box at the right side of the figure) should be based on studies of human perception and judgments regarding scenic degradation caused by air pollution (such as the study presented in this paper) as well as on studies of the feasibility and cost of emissions control technologies and siting policies necessary to protect visibility. Regulations should be promulgated in a logical step-wise manner, starting with a criteria document describing the effects of various pollutants and the concentration levels necessary to protect scenic resources. Then, the equivalent of an air quality standard or a prevention of significant deterioration increment could be established based on these criteria. Standards could be stated in terms of quantitative specifications of visibility impairment, such as visual range, contrast, chromaticity, or ΔE, or in terms of extinction (scattering and absorption) coefficients or concentrations of total suspended particulates, fine particulates, and NO_2. Regulations and long-range strategies would be based on these standards and on the feasibility and cost of emissions control technologies.

Once regulations and standards are promulgated, decisions regarding emissions control retrofits on existing sources and permits for new sources can be made based on measurements of existing visibility impairment and/or model predictions of future impacts.

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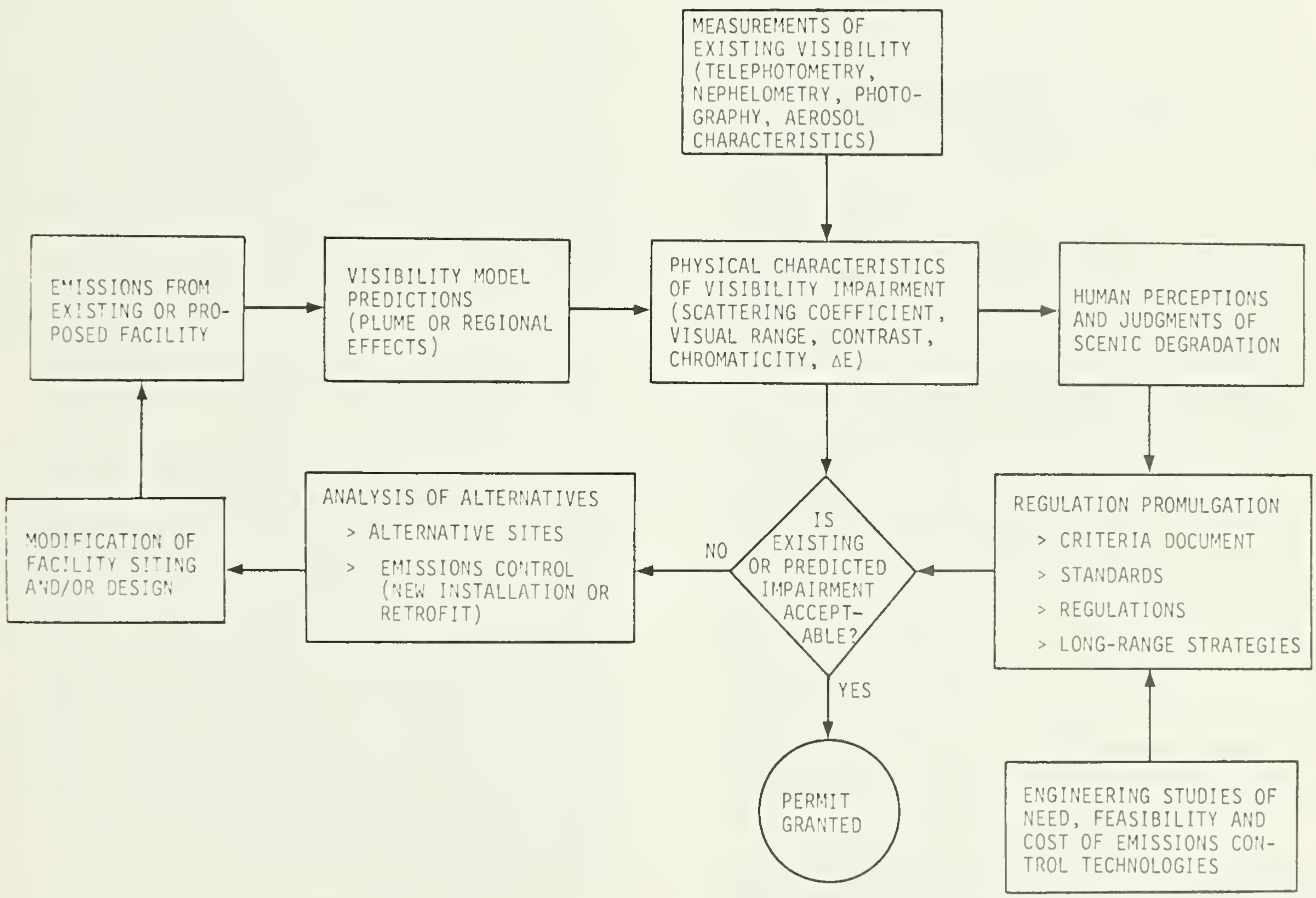

Figure 2.--Schematic logic diagram of regulatory actions necessary to restore and protect visibility in Class I areas.

Psychophysics and Visibility Values[1]

Ronald C. Henry[2]

Abstract.--As visual psychophysics is the study of the relationship of physical stimuli and visual perception, it is natural domain for the study of visibility degradation by the atmosphere. Current theories of visibility in the atmosphere date from 30 to 50 years ago and, therefore, do not use significant new psychophysical results and methods. These methods can be used to quantitatively predict the visibility of contrast detail and just-noticeable differences in complex scenes. By connecting the results of psychological studies and air quality modeling, a modern psychophysical model of the visual system could be used to predict allowable levels of development consistent with protecting perceived visual quality. Visibility degradation caused by discoloration is insufficiently understood to be quantitatively predicted at the present time. Several ambiguities of the C.I.E. color system is discussed. Finally, it is recommended that all visibility studies include direct visual psychophysical measurements and human subjects be screened by vision experts.

INTRODUCTION

How do people judge the visual clarity of the air? What is an appropriate measure of just-noticeable differences in scenic vistas? What is a perceptible color difference? These are just some of the questions raised by the visibility protection for Class I areas required by the Clean Air Act Amendments of 1977. It is the thesis of this paper that current visual psychophysical theory is well suited to answer questions such as the above in a noncontroversial, quantitative manner and that psychological measures of visual quality are most useful when related to modern psychophysical concepts of vision.

The branch of science responsible for the study of the interrelations of physical stimuli and mental processes is psychophysics and as such, the questions raised above are properly in its domain. Value judgements and human reactions to visual stimuli are psychological questions. The degradation of visual quality is best described by a chain of processes: the physical light scattering phenomena, the psychophysical response of the observer to the incident light and the psychological interpretation of the psychophysical image. It is important to note that visual psychophysics is the natural link in the chain between the physical optical properties of the atmosphere and the resultant human reactions. Yet, all current theories of visibility degradation assume either implicitly or explicitly psychophysical theories of vision which are 40 to 50 years old, particularly in the realm of contrast perception, which is central to the calculation of visual range. Totally new theories have supplanted the psychophysics of contrast perception incorporated in the work of such pioneers as Middleton and Koschmeider. Unfortunately, the psychophysics of color perception are still not well understood. Present methodology as applied to atmospheric coloration does not take sufficient notice of important psychophysical processes in color vision, especially chromatic adaptation. The next section will discuss the implications of current visual psychophysics to visual range and contrast reduction. Following it is a brief critical review of the C.I.E. color matching methodology as applied in published calculations of atmospheric discoloration. Finally a list of conclusions and recommendations is given.

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[1]Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

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PSYCHOPHYSICS AND CONTRAST REDUCTION

> "Shadows appear to be of supreme importance in perspective, because without them opaque and solid bodies will be ill defined; that which is contained within their outlines and their boundaries themselves will be ill understood unless they are shown against a background of a different tone from themselves." - Leonardo da Vinci, six books on Light and Shade (Richter 1883).

By perspective, Leonardo included not only linear perspective, but what he called the perspective of disappearance and the perspective of color (i.e., the way the distinctness of colors and objects change with distance. To this day, his books on these subjects constitute the single most complete set of observations by a scientist/artist of the effect of the atmosphere on visual and scenic values.

In the passage quoted above for "shadow," we may substitute "contrast" without doing harm to the content or intent of the original. The alteration of contrast by the atmosphere in its most important optical effect, both from the point of view of aesthetics and practical concern with safety of travel by airplane, ship, or autos. The contrast of an object with its background decreases exponentially with distance. When the contrast becomes very small, the object will no longer be visible. This is called the liminal contrast and has been the object of a great deal of psychophysical study. Indeed, the choice of a liminal contrast of 2% or 5.5% has been the only psychophysical property of the eye-brain commonly considered in calculations of visual range.

Before going further, we must question the use of visual range as a measure of visual or scenic quality. Historically, the current concept of visual range was developed to meet the obvious needs of aviation. As such, it is most useful for large objects at or near the contrast threshold under low visibility conditions. It is not likely that the intent of Congress in mandating visibility protection in Class I areas was to protect the safety of travellers in national parks during bad weather. How then does the concept of visual range apply to small changes in scenic vistas under conditions that are far from contrast thresholds and when visibility is excellent; especially since visual range is usually defined with regard to a hypothetical observer with a constant 2% liminal contrast. To believe that all the qualities of a natural landscape have the same contrast threshold is obviously contrary to observation. To quote Leonardo again,

> "Therefore, O Painter, make your smaller figures merely indicated and not highly finished, otherwise you will produce effects opposite to nature, your supreme guide. The object is small by reason of the great distance between it and the eye, this great distance is filled with air, that mass of air forms a dense body which intervenes and prevents the eye from seeing the minute details of the objects.
>
> "Whenever a figure is placed at a considerable distance, you lose first the distinctness of the smallest parts; while the larger parts are left to the last, losing all distinctness of detail and outline. . . ."

Even if visual range predicts the maximum distance, a large dark object would be visible, what is its quantitative relationship to the smaller contrast detail which will be lost first and is much more noticeable to human observers? It is easy to imagine situations, particularly when the light scattering particles are inhomogeneously distributed, where the visual range is unaffected but the smaller details on mountains or hills are not visible and vice versa.

This paper proposes that the visibility of contrast detail be considered as an important quantitative measure of atmospheric clarity. Contrast detail can be classified by the visual angle it subtends, for example one could define a scale of contrast detail as in Table 1. This scale is similar to the Form, Line, and Texture classification which has been proposed by the Forest Service; Form corresponding to very coarse detail and Line and Texture to coarse and medium/fine detail, respectively. Also, given in this table is the calculated visual range of each level of contrast detail to be expected in the West and East given different background visual ranges.

The visual ranges and the chosen size ranges of contrast detail in Table 1 are based upon the most recent psychophysical theories of the visual system. The approach taken is analogous to linear system theory as applied in electrical engineering. The basic method is to measure the magnitude of the response of a system to sine waves of varying frequencies; this is called the modulation transfer function (MFT). The response of the system to an arbitrary input can then be calculated by using Fourier analysis to represent the input as a

Table 1.--Visual range of contrast detail

Detail of Level	Characteristics Size at 10 Km (m)	Examples for a Hillside at 10 Km	Visual Range (Km) West (V_R=100 Km)	East (V_R=20 Km)[a]
Very Coarse (Form)	>100	Hills, valleys, ridgelines	79	16
Coarse (Line)	50-100	Cliff faces, smaller valleys	76	15
Medium (Texture)	25-50	Clumps of large vegetation, clearings on forrested slopes	62	12
Fine (Texture)	<25	Individual large trees, clumps of small vegetation	22	4

[a] V_R is the assumed background visual range

sum of sine waves; the response to the arbitrary input is the sum of the response to its component sine waves, which is known from the MTF. This method has been extremely successful in engineering and physics. In psychophysics, it is the basis for modern theories of the auditory system. Only recently has it been realized that a similar approach can be taken to visual stimuli (Campbell 1974). This is a bit difficult to grasp intuitively as the sine waves are varying in space and not in time (i.e., the sine waves are light patterns, a series of dark and light bars, the higher the spatial frequency the closer together are the bars). An example of this method is outlined in Figure 1. In this figure, the Mach Band phenomenon is explained by the use of modern visual psychophysics. When a steadily decreasing luminance gradient is observed, the perceived brightness does not appear to uniformly decrease, but two bands, one light and one dark, are seen. The name derives from the great physicist and psychophysicist, Ernst Mach, who was the first to scientifically describe this effect. The purpose of this illustration is to give an indication of the power of modern psychophysics to describe the complex dependence of perceived brightness on incident light patterns. A related phenomenon can be observed by noting the light band just above a dark colored horizon. A brief but more complete discussion of this approach to vision through the atmosphere is found in Henry (1977), and further background information can be found in Campbell (1977) or Cornsweet (1970).

Extensions of this theory are possible. Of most direct application to the CAAA would be a theory to predict just noticeable differences at suprathreshold levels in complex scenes.

This theory would be used in the following methodology:

1. The psychophysical response of a standard observer is defined in terms of an average Modulation Transfer Function.

2. Photographs of the scenic vistas in question are digitized and reduced mathematically to component sine waves.

3. The psychophysical linear system model of the visual system predicts the contrast reduction which would cause a just-noticeable difference in the scene.

4. Light scattering calculations and air quality models are used to relate this contrast reduction to allowable emissions.

A procedure as outlined above would reduce the subjectivity of the visibility decision making process and quantify the justification for limiting emissions to protect scenic vistas.

The critical question is what is a "just-noticeable difference"? This concept has a precise psychophysical meaning based on the outcome of a forced choice experiment and can be calculated by existing, validated models of the visual system. The great unanswered question concerns the feelings of the observer towards the just-noticeable difference. What is the nature of the psychological reaction to the psychophysical response? Does a small psychophysical change in the scene produce a large psychological response? These questions should be addressed by future experimental studies.

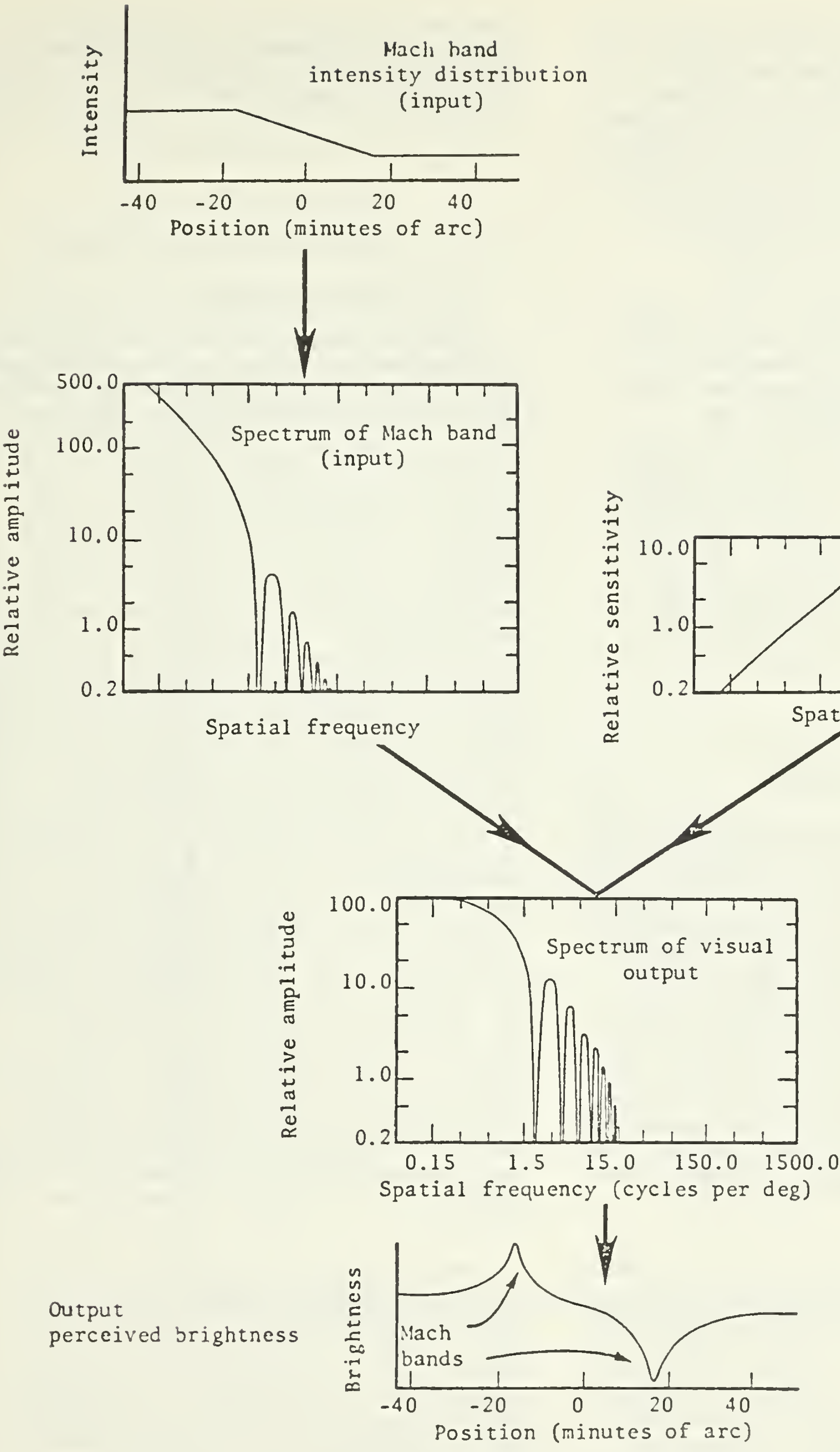

Figure 1.--Mach bands explained by MTF approach (adopted from Cornsweet 1970).

But why go to all the trouble of relating the physical change to the psychological response through a new and complex psychophysical method? Why not relate the physical change directly to the psychological response by a direct experiment? The answer is that the results of any direct psychological study are limited to the range of vistas and conditions studied. There is little ability to extrapolate the results in a quantitative manner.

The psychophysical methodology is applicable to scenic vistas, agricultural, suburban and urban or any concievable scene, and it is based on firm, quantitative laboratory experiments. By combining psychological and psychophysical methods, predictions of just-noticeable differences in scenic vistas would rest on our understanding of the visual system itself and not a series of ad hoc experiments, the conclusions of which, whether right or wrong, would be debated endlessly. In brief, psychophysical methods cannot predict how an observer will feel about a just-noticeable difference in a scenic vista, but it can predict the occurrence of a perceivable change in the vista.

THE PERCEPTION OF COLOR THROUGH THE ATMOSPHERE

A natural or polluted atmosphere can alter colors by wavelength dependent scattering and absorption from particles and/or absorption by colored gases, predominately nitrogen dioxide. The relative importance of these two mechanisms in polluted air has been discussed by Horvath (1971), Waggoner et al. (1972) and Husar and White (1976). No definitive conclusions have been reached, although both particles and gases may be capable of producing a "brown cloud" of polluted air. The effects of pollution on the human perception of color have not been studied directly. The above cited works have relied on the psychophysical methods implicit in the C.I.E. (Commission Internationale de l' Éclairge) color system, the shortcomings of which will be discussed below.

No adequate theory of color vision exists. The C.I.E. system which has been used to predict colors of the atmosphere was not intended to be a theory of color vision. It is an engineering solution to the problem of setting color standards for world trade. As a method of defining a standard color system for paints, textiles, etc., the C.I.E. method works. However, its applicability is questionable for judging colors in the atmosphere of various sized objects, plumes or haze layers under nonstandard lighting conditions against varying colored surroundings. Even the variations in time of the color of a plume may be important. The following is a partial list of parameters of importance to perceived coloration other than the wavelength distribution of the light:

- Size of the object or area
- Background luminance level
- Color of surrounding background
- Temporal variations.

Each of these parameters has been shown to have a potential effect on perceived color as large as has been predicted for a polluted atmosphere. Figure 2 shows 12 colors that are identical as judged by the C.I.E. 1931 standard observer with a 2° field of vision but are all different as perceived by the C.I.E. 1964 standard observer with a 10° field of view. Obviously, the size of the field of view is important, since the range of variation shown in Figure 2 is about as large as the color changes predicted for Los Angeles smog by Husar and White (1976). The work of Hunt (1953) shows very large movements of perceived colors on the standard chromaticity diagram due to changing only the luminance level of the stimulus. More recently Kelly (1974) has shown that the three color mechanisms in the human retina all have different space and time sensitivities. Furthermore, Kelly shows that the visual effects of time and spatial variations are not independent. The effects noted by Kelly are not small and could influence the color threshold of a turbulent, moving power plant plume. The effect of the color of the surround on perceived color is well known and is called chromatic adaptation. In general, if the eye is adapted to a color, say blue sky, a nearby white area may take on the complimentary color of the surround, in this case a light yellow-brown. Again, this effect is large enough to explain some of the brown color of atmospheric haze. Note that clouds normally look white because they are partially illuminated by the blue light of the sky, thus eliminating the chromatic adaptation effect; dark, low clouds do often appear to be brownish.

The actual colors of the sky have been studied extensively. Figure 3, adapted from Wyszecki and Stiles (1967) and Judd et al. (1964), shows their results for the range average sky color. This work was based on and compared with a large number of independent, direct visual colorimetric and spectrophotometric observations of unpolluted atmospheres, e.g., Chamberlin et al. (1963). Because of chromatic adaptation, any color in the cross-hatched area of Figure 3 above an x value of about 0.30 to about 0.37 could be considered to be "white". Most calculations

of the effects of pollution on sky color do not lie outside the cross-hatched area. The usual "circle of confusion" of colors on the chromaticity diagram has not been considered as this effect is small compared to the others discussed above.

CONCLUSIONS AND RECOMMENDATIONS

The perceived psychophysical effects of polluted or pristine atmospheres on contrast and color are not well understood. The documented effects of size, shape and surrounding background on visibility of contrast and color are significant and are not adequately addressed in any current visibility model. In the area of the visibility of luminance contrast recently developed, psychophysical methods will probably be sufficient to produce a useful model. The case of coloration effects is not presently amenable to any theoretical approach. The following recommendations are made:

- Development of psychophysical models of the human response to contrast reduction based on the Modulation Transfer Function (MTF) approach.

- The relationship of psychological estimates of visual scenic quality to psychophysical parameters needs to be studied experimentally.

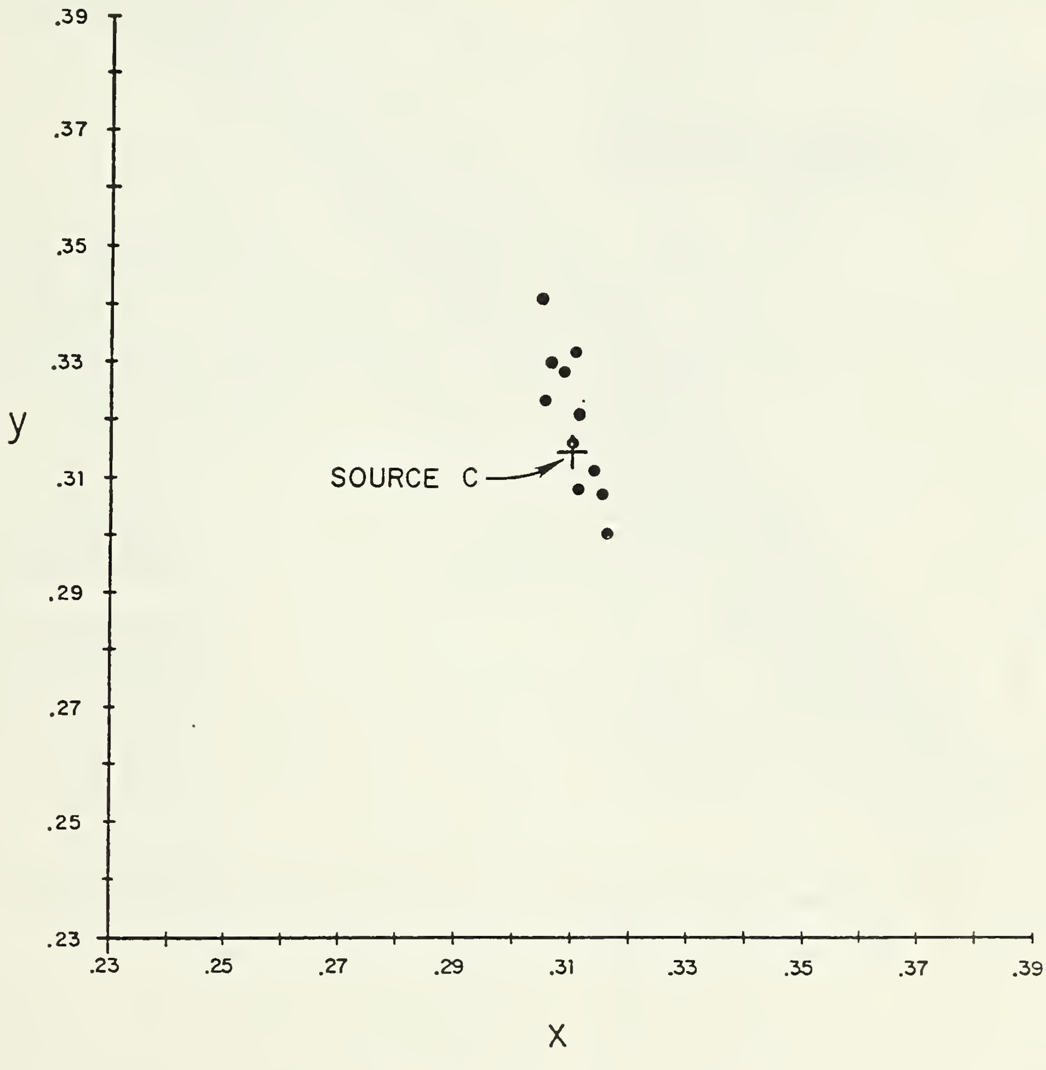

Figure 2.--Example of 12 colors (different wavelength mixtures) that are identical to standard source "C" for the 1931 CIE standard observer (all have the same chromaticity +) but which, as seen by the 1964 large field observer, all have different chromaticities (•), adopted from Wysyecki and Stiles, 1967.

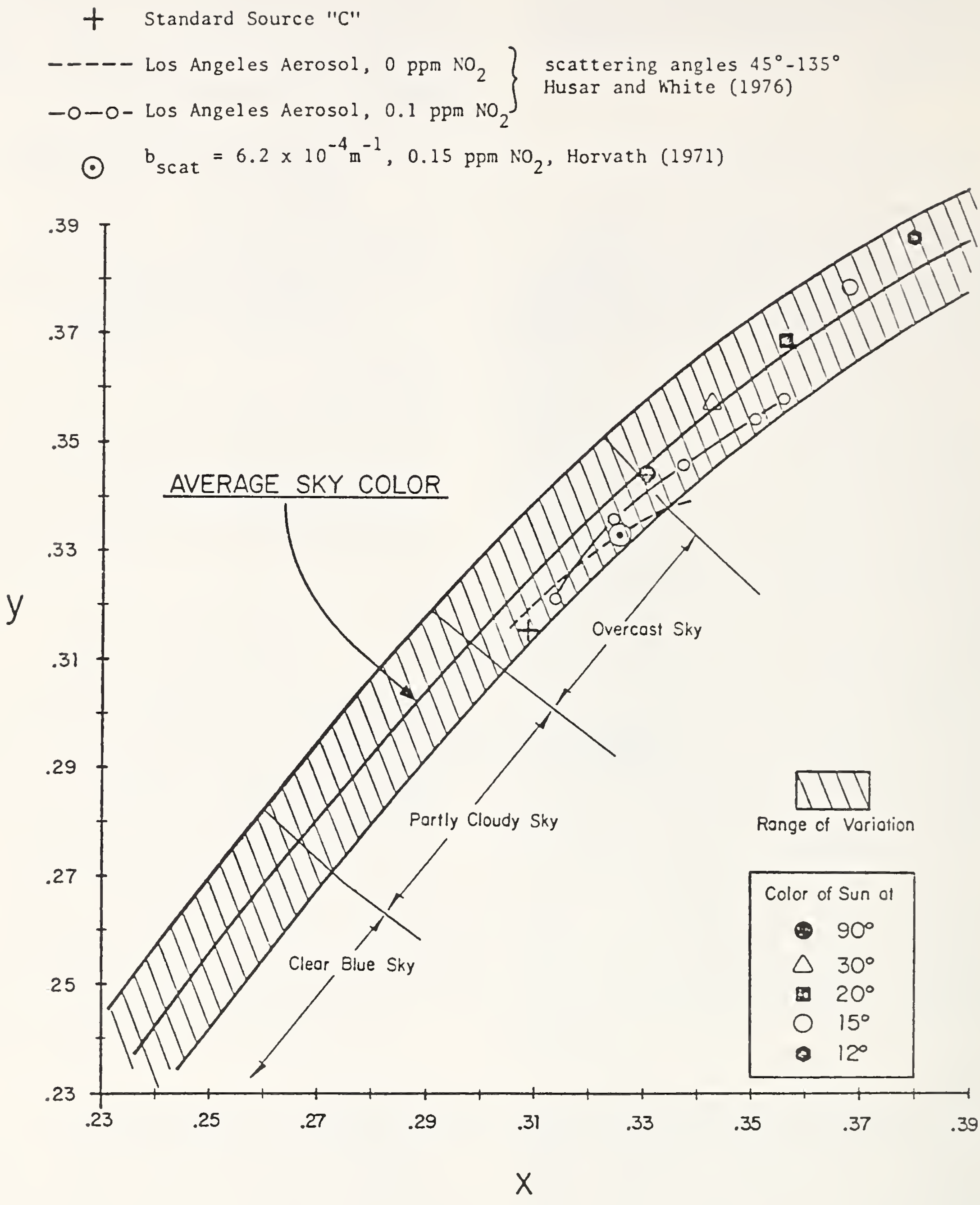

Figure 3.--Typical chromaticities of the sky (adapted from Wysyecki and Stiles 1967) with calculated chromaticities of pollution haze layers.

- Direct field measurements of psychophysical brightness estimates should be included in all visibility studies, along with screening of all subjects by measuring their visual modulation transfer function.

- Immediate formation of a national or international multidisciplinary committee to recommend and direct studies necessary to define coloration standards appropriate to ambient atmospheric condition.

- Initiate studies evaluating current visibility measurement methods (airport visibility, photography, plume opacity) in light modern psychophysical knowledge.

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The Visibility Problem: Behavioral and Social Perspectives

The Daniel paper provides a transition from the last section to the current one. While Daniel describes psychophysical techniques that could be used in measuring visibility, he also suggests a broader behavioral model for assessing visibility. Ulrich contributes a unique strategic approach by advocating psychophysiological studies or visibility assessment. Driver and his colleagues stress the importance of direct assessment of social values that relate recreation needs and visibility. Loomis and Greene amplify this emphasis on social values, but also consider the importance of understanding public reactions to impaired visibility in Class I lands. These authors also call for an integrated attack on the research problem of visibility. An example of a highly integrated approach to assessing visibility is provided by Craik in the final paper of this section.

Psychological Perspectives on Air Quality and Visibility in Parks and Wilderness Areas[1]

Terry C. Daniel[2]

Abstract.--The relationship of the visual system to visibility issues is explored and a specific application of a method for assessing scenic beauty is proposed as a tool for visibility research. Additional issues in the assessment of visual quality are discussed.

According to one statement the goal of the 1977 amendments to the Clean Air Act is "the prevention of visibility impairment from man-made air pollution and the restoration of natural visibility in Class I Federal areas" (Federal Register, 1978). Other statements and discussions of the motivation for this recent action present similar statements. Apparently it has been decided that in addition to being life and health sustaining, air in Class I areas should also be clear and free of any man-caused impediments to vision.

The Clean Air Act Amendments refer directly to visibility, defined in terms of visual range and the absence of discoloration. There may be a number of human values associated with visibility, including perhaps the simple opportunity to see clearly over great distances. The major impetus for the clean air amendments, however, is to protect natural scenic values in Class I parks and wilderness areas. If atmospheric pollution should significantly impair man's ability to see and enjoy the cultural, biological, and geological features that these unique areas provide, the values that motivated their preservation and protection would be reduced.

In some instances the negative effects of man-generated air pollution may be substantial and unambiguous, as when a concentrated plume or "cloud" completely obscures views of scenically important landscape features. Determining the more subtle effects of smaller, less concentrated air pollutants on natural visibility and scenic values, however, requires more sophisticated assessment procedures.

Two general approaches are possible in the effort to measure the effects of atmospheric pollution on visibility values in Class I areas: direct assessment of visibility (or visibility impairment), and assessment of indirect effects of atmospheric pollutants on scenic beauty values. The procedures and problems involved in both approaches are very similar, but the resulting measures (or indices) have different implications. Direct assessments of visibility may offer somewhat more "objective" indices of the effects of air pollution, but the relationship between visibility indices and social or human values would have to be separately determined (or assumed). Assessments of atmospheric effects on landscape scenic beauty would only indirectly reflect changes in air quality parameters, but in many respects scenic beauty indices would more directly represent the values that motivated the Clean Air Act Amendments.

Both direct and indirect assessment approaches are discussed in the following pages. The perspective taken is that of a psychologist, particularly reflecting the paradigm that guides much of the contemporary study of human perception. The use of Perceived Environmental Quality Indices (Craik & Zube, 1976) is advocated as a means of assessing visibility values. Daniel and Zube (in press) provide a review of human-perception based assessments of natural resource values in the context of several specific applications to the evaluation of landscape, wildlife, wilderness, and recreation resources. The fact that perceptual assessments have been successfully applied in these and other contexts indicates that such methods could provide an important and effective contribution to the implementation of the Clean Air Act Amendments in Class I parks and wilderness areas.

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[1]Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

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ASSESSING VISIBILITY

Measuring any property of the environment requires an interaction between theoretical conceptualizations, including a set of definitions and assumptions about the property being measured, and concrete operations by which observations are made and numbers assigned. The definitions and assumptions indicate what operations are relevant, and the operations that are actually performed imply modifications and additions to the original definitions and assumptions. In the end it is difficult to tell whether theoretical conceptualizations determined the measurement operations or *vice versa*. Strict operationalists hold that all concepts are defined by the procedures (operations) by which they are observed and measured. In the context of environmental quality assessment, however, the shortcomings of current measurement methods are often noted and efforts continue to develop measures more closely representative of theoretical conceptualizations of the properties being assessed.

Neither the definitions nor the operations needed to assess visibility have been firmly established. Nonetheless, implementation of the Clean Air Act Amendments requires that visibility be assessed in all Class I areas. Visibility assessment is necessary if "visibility impairment from man-made air pollution" is to be identified and if progress is to be made toward restoration of "natural visibility." Thus, some theoretical conceptualization of *visibility* must be developed and/or some operations for measuring visibility must be devised.

Visibility and the Visual System

Vision typically begins with light (electro-magnetic energy) radiated or reflected from the surface of some object in the environment. The light passes through the atmosphere and makes contact with appropriate receptor cells in the eye. Stimulation of the receptors initiates activity in specialized regions of the nervous system that (in ways not fully understood) produce a variety of effects, including the experience of "seeing."

The end product of this visual system, the seeing, depends upon every link in the chain. If the light energy is not of sufficient magnitude or if it is of the wrong "type" (for humans wavelengths less than about 400 nm or longer than 700 nm), no seeing will result. If the light energy is obstructed, absorbed, scattered, or otherwise rearranged by the atmosphere between the object and the receptors the object may be seen quite differently, or not at all.

The components of the system that are internal to the organism impose their own constraints and modifications on what is seen. Identical physical inputs to the system may on one occasion produce strong effects, and on another be "ignored." This system can detect the light of a single candle at 30 miles, and yet fail to notice a Greyhound bus in the adjacent lane on the freeway. Objects that are "not there" (not represented by appropriate light energies) or that could not even possibly exist may nonetheless be "seen." Depending upon expectations, interpretations, and other factors, the same object, lighting, and atmospheric conditions can result in a different object being seen (Figure 1).

Figure 1.--An example of the perception of a "non-existent" figure. While the white triangle (left figure) and pear-shaped object (right figure) are perceived by everyone, there is in fact no difference in brightness between those figures and the background. These "subjective contours" are but one example of the effects of the perceiver on what is seen.

It is clear in the context of the Clean Air Act Amendments that concern is focused upon the effects of the atmosphere on the visual system. However, it is important to bear in mind that this is only one element in a complex and highly interdependent system. Any atmospheric effects on vision will depend upon features of all of the other elements in the system; the object being viewed, the characteristics of the light reflected from it, and the relative location and other characteristics (including attitudes, expectations, and intentions) of the observer.

Some of the complexity inherent in the concept of visibility could be reduced if all elements of the system except the characteristics of the atmosphere were held constant. A standard object could be placed at some fixed distance from a selected observer and then, under different atmospheric conditions, the observer's ability to see the object could be determined. In psychological terminology this is a *detection* experiment, one of the most basic and sensitive

tests of the vision system. The observer is required only to determine whether something is there (is visible) or not. Atmospheric effects on visibility then would be reflected in the observer's ability to detect the standard object. Under very clear conditions, the observer should detect the object easily, and under very hazy conditions, the object may not be detected at all.

Unfortunately the simple dichotomy implied above in detection and non-detection of the object (you either see it or you don't) does not represent the real outcome of such experiments. While outcomes may be unambiguous at the extremes of atmospheric conditions, at many intermediate (more normal) levels there may be considerable uncertainty about whether the object can be seen or not. Under such conditions psychologists (being generally suspicious and untrusting of their fellow man) often introduce "catch trials" -- unbeknownst to the observer the object is removed and then the observer is asked whether he can see it or not. Depending on the observer and the conditions under which he is asked to make and report his observations, the nonexistent object can be "detected" with an alarming frequency. One solution to such problems with the measurement of detectability (visibility) is to avoid any dichotomous, "all-or-none" indicators. Instead, detectability is gauged in terms of the probability that a given object can be detected under specified conditions. The detection probability must be adjusted by the probability that the observer will report "detecting" the object when it is in fact not present.

The resulting numerical indices (usually transformed to some standard scale) provide a continuous measure of detectability that may be applied in a variety of ways. If we wish to determine the differences between observers in their ability to detect objects, each observer would be asked to detect the same object(s) under identical conditions. The observer with the highest detection index (adjusted for false detections on catch trials) would be the most perceptive.

A detection index could be used to measure the effects of atmospheric conditions on visibility. In this application a standard object (or set of objects) would be shown to an observer under different atmospheric conditions. The detection index would provide a measure of the effects of the different atmospheric conditions on visibility/detectability. Of course the index obtained for a given atmospheric condition would apply only to the specific object, lighting conditions, observers, and observer-contexts represented in the assessment. Generality across objects, lighting, and observers must be established by additional empirical studies and theoretical extrapolations.

As stated above, indices of detectability would provide the most basic and sensitive measures of the performance of the vision system. Other related methods for assessing visibility might require an observer to identify specific objects (rather than just judge whether something is present or not); to discriminate between objects that differ along one or more dimensions; or to distinguish particular features of an object (e.g., size, shape, color). The types of objects used could range from specially designed experimental targets, such as rods, spheres, cubes, or patterns of different sizes and colors, to endemic objects such as trees, rocks, or mountain peaks. Variations in types of observers and observer conditions could be introduced and may prove important. For instance, observers familiar with the area and with the target objects may be more or less affected by different atmospheric conditions than observers who are unfamiliar with either the area, the targets, or both. Regardless of which approach or combination of approaches is employed, all elements of the visual system must be taken into account before meaningful measures can be obtained of the effects of any one of the elements.

Natural Visibility

When the label "natural" is applied in contemporary American society it almost always refers to something uninfluenced and unaffected by *Homo sapiens*. This interpretation is not universal, as manicured gardens, cultivated pastures, and carefully managed forests are frequently viewed as "natural" environments in other parts of the world. Indeed there is considerable inconsistency in the American use of the term. Intensively managed forest scenes are frequently judged to be higher in "natural beauty" then unmanaged wilderness areas when the judges are given no extra clues (such as verbal labels) to distinguish the scenes (Daniel, et al., 1973; Zube, 1974). On the other hand, instructing observers that a forest scene is in a "natural wilderness area" increases its judged natural beauty, whether the scene is in fact wilderness or is in an intensively managed forest (Anderson, 1978). Also, even the most adamant preservers of nature will rarely find an ancient Indian ruin or even a decaying old Trapper's cabin to be objectionable or "unnatural."

Distinctions between the "natural world" and the "human world" implies a dichotomy that may be illusory. The current state of the planet is the product of an evolutionary process of substantial duration. Man, in one form or

another, has been an integral (perhaps even a natural) part of this evolutionary process for thousands of years. Granted that such a short period is only a moment in the total evolutionary process, but it has produced irrevocable influences on that process. Efforts to "undo" previous effects can only introduce different and perhaps additional effects. In the end there is not a choice between a natural and a man-influenced environment. Man's influence on the environment is cumulative and continuous and inevitable. Within the limits of human knowledge and ability, man can at best only choose among alternative environmental effects.

The term "natural visibility," as used in the Clean Air Act Amendments, again focuses upon the atmosphere element in the visual system. It means the visibility that is possible when the atmosphere (through which the light must pass) is filled with "natural air." If "natural air" is taken to mean air that evidences no human influences, then it is highly unlikely that any such air exists near the planet earth. (If we could agree upon the recipe for natural air, however, we might be able to manufacture some.) Natural visibility, then, must in practice mean the visibility that is (or could be) achieved if the effects of identifiable (relatively modern) man-caused elements in the atmosphere were absent.

Even if an area could be found where the air is natural (or is close enough to be acceptable) there would be several problems with measuring visibility. First, natural atmospheric conditions are highly variable within the day, and from season to season. The amount of water vapor, dust, and a host of other elements (some of which are responsible for our highly-prized blue sky and colorful sunsets) are constantly changing and vary from one part of a given region of the atmosphere to another. Because of this variability, visibility measured at any one time or place in an area will differ from that at other times and places.

The nature of the object that is being viewed will also affect measures of visibility. Objects of different sizes, colors, shapes, and that are more or less familiar to the observer will result in different measures of visibility. The angle, intensity, spectral configuration, and other aspects of the light that illuminates the object will also affect visibility. Finally, the location, visual sensitivity, expectations, intentions, and experience of the observer can be expected to influence the measures obtained.

In the face of such variability, which measure of visibility should be used to represent the natural visibility of an area? Options include the highest value found, the lowest value, the most frequent value, the average value, the 90th percentile value, or any of an infinite number more. Perhaps visibility should be represented by a set of measures; for example, the average values obtained for each month, for each season of the year, or for each different type of observer. There are advantages and disadvantages of all of these options. The particular approach chosen will have important implications for the meaning of the visibility measure and for its sensitivity to changes that may occur because of the introduction of man-caused elements into the atmosphere.

Air Pollution vs. Visibility Impairment

Concern about air quality or, conversely, air pollution has a longer history than concern about visibility impairment. (Evidence suggests, however, that much of the concern about air pollution is based upon visual effects of pollutants.) There have been many discussions and studies regarding air quality, and a number of air quality indices have been developed. These indices are based on the notion that purer air is better air. Thus, the lower the concentrations of certain identified elements or pollutants (e.g., carbon monoxide, sulfur dioxide, and photochemical oxidants) the higher the quality of the air. Different indexing systems obtain and combine measures of these pollutants somewhat differently, and there is general agreement that no one index includes measures of all of the potentially harmful or undesirable elements that may be in the atmosphere. Nonetheless, reasonably acceptable physical measures of air quality seem to have already been developed.

In general, low quality air (air with a lot of "stuff" in it) provides for less visibility than higher quality (purer) air. More detailed relationships between air quality and visibility, however, have not yet been established. The work of Latimer and his associates (Latimer and Samuelson, 1978; Latimer, et al., 1978) indicates important relationships and confirms that both "natural" and "man-caused" elements in the atmosphere separately and in interaction may have effects of visibility. This work and others clearly indicates that there can be no simple relationship between overall physical-based indices of air quality and visibility. The type, particle size, and distribution of elements in the atmosphere is far more important to visibility than is the gross volume of "pollutants." The existing physical-based indices of air quality, then, do not offer any direct or precise indications of visibility.

The effects of atmospheric elements on visibility must be determined by direct empirical observations, or by means of theoretical

models. Empirical studies, such as the detection experiments described earlier, could be used to measure rather precisely the visibility associated with any given atmospheric conditions. Observers selected on the basis of some (perhaps random) sampling scheme might be required to detect (or identify, or discriminate, etc.) some object or set of objects under various air quality conditions. Lighting, observer expectations and other factors might be held constant or systematically varied. Based upon the observers' performance, indices of visibility could be calculated using signal detection theory methods (Green & Swetts, 1966; Swetts, 1973) or some other psychological scaling procedures (e.g., Torgerson, 1958).

The derivation of visibility indices by means of strictly physical-based models requires that the characteristics of light propagation, of atmospheric elements, and observer sensory and perceptual processes all be known or assumed. Given the current state of knowledge regarding all of these processes, it seems inadvisable to rely entirely on such models. At the very least, some direct empirical studies would be required to validate model results. Better still, the direct empirical approach and the theoretical model approach should be combined, each guiding and correcting the other in the effort to establish relationships between air quality parameters and visibility. For the present, however, these relationships are not known for certain and so a distinction must be maintained between air quality and visibility.

Establishing Impairment Standards

If all man-generated or influenced elements in the atmosphere could be removed and prohibited from Class I areas, the attainment of natural visibility would be assured. The conceptual problems associated with such an undertaking were touched on earlier. The technical, economic, and political implications of this approach to achieving natural visibility are substantial, but outside the scope of the current paper. On all of these counts eliminating man-associated elements entirely from the air in Class I areas is not a reasonable (perhaps not even a desirable) approach. A more practical approach is to identify some set of elements that produce visibility impairments and determine what conditions of concentration and distribution produce unacceptable departures from natural visibility.

Establishing limits for man-caused visibility impairment presumes the ability to determine visibility in natural air and then to measure the amount of change in visibility as concentrations of man-generated elements increase. At some point, visibility impairment (relative to whatever is defined as natural visibility) will be designated as unacceptable and some action may be required to halt or reverse the inflow of the responsible elements (assuming they have been adequately identified). Determining how much visibility impairment, how much change from natural visibility, will be accepted is a complex matter involving interactions among technological, economic, and political processes. Reliable measures of visibility or visibility impairment, however, are an essential prerequisite to the setting of any standards.

ASSESSING SCENIC BEAUTY

An alternative to direct assessments of visibility is to measure scenic beauty in Class I areas. By this approach the effects of changes in air quality on the scenic value of landscape features would be determined. While this approach may provide a less direct assessment of the effects of atmospheric pollutants, it may be a more direct measure of effects on the values the Clean Air Act Amendments are intended to protect.

Many of the problems discussed in the context of visibility assessment also apply to the measurement of scenic beauty. Some conceptualization of what scenic beauty is must be developed and procedures for measuring changes in this property of the environment must be established.

The Scenic Beauty Estimation Method

Assessing the effects of air quality on scenic beauty requires precise measurement, as effects may often be very subtle. The Scenic Beauty Estimation (SBE) method (Daniel & Boster, 1976) provides a means of obtaining quantitative indices of the perceived aesthetic quality of landscapes. Based on the perceptual judgments of human observers, the SBE index has proven a sensitive and reliable gauge of landscape scenic quality. The method has been successfully applied to a number of different landscape assessment problems (e.g., Benson, 1974; Daniel, et al., 1973; Daniel, et al., 1977; Schroeder & Daniel, in press).

The SBE index for a given landscape scene is obtained by an analysis of the aesthetic judgments of a panel (or panels) of human observers. The observers are presented with a number of scenes, either directly or by means of a photographic (or other) representation and asked to rate each scene on a 10-point scale ranging from "Extremely low scenic beauty" to "Extremely high scenic beauty." Each member of the panel independently rates each scene. A

psychophysical scaling model is employed to derive a standardized relative index of perceived scenic beauty for each scene based upon the ratings assigned by the individual observers. The scaling procedure is described in detail in Daniel and Boster (1976).

While no attempt has yet been made to assess the effects of air quality on scenic beauty, the application of the SBE method would appear straightforward in this context. A preliminary study in this regard is currently underway (Latimer & Daniel, 1979).

Air Quality and SBE's

To apply the SBE method in the context of the Clean Air Act Amendments, the perceived scenic beauty of Class I areas would be assessed under different atmospheric conditions. It might be expected that scenic beauty values would be primarily determined by landscape characteristics under very clear conditions. Inherent scenic values may be reduced under very hazy conditions. Some atmospheric conditions that result in obstructed visibility may, however, produce positive effects on scenic quality. Clouds surrounding a lofty mountain peak, fog along a sea coast, or a colorful sunset viewed through a moderate haze all provide examples where departures from clean air may produce positive aesthetic effects. On the other hand, when atmospheric obstructions block the view of an important landscape feature, or obscure the inherent texture or colors of the land and vegetation, negative effects may occur. The effects of less dramatic atmospheric changes may be more subtle, but they could be significant given the very high standards that seem to be implied by the Clean Air Act Amendments.

As with the more direct assessment of visibility, measurement of scenic quality implications of atmospheric conditions presents some problems. Natural variations in the atmosphere and lighting conditions must be taken into account. The characteristics and contexts of the observers who are asked to judge scenic beauty will also be a factor, perhaps even more so than when more direct visibility measurements are required. The most important extraneous factor, however, will be the inherent characteristics of the landscape being judged. Scenic beauty values will vary from one landscape scene to another even though atmospheric conditions are constant. It is very likely that the characteristic of the landscape will interact with air quality, producing complex effects on scenic beauty values. For example, a concentrated plume may substantially degrade scenic values in an open canyon-lands setting, but may have only minor effects on values in forested mountainous terrain. General haze may have different effects depending upon the extent of views and on the form and color of important landscape features.

In spite of the obvious complexity of the task, there seems good reason to expect that atmospheric effects on scenic beauty could be measured with substantial precision and reliability. The effects of lighting conditions and observer variables could be separated by appropriate design and statistical procedures from the effects of relevant air quality changes. Whether scenic beauty judgments will be more or less sensitive to the effects of man-generated pollutants in the atmosphere than will direct visibility measures is an empirical question. Whether scenic beauty or visibility measures (or both, or neither) are the most appropriate or best means for implementing the Clean Air Act provisions for Class I areas will probably be decided in some other arena. Whatever measures of "natural visibility" and "visibility impairment" are established, it will be important to determine the relationship of those measures to human visual responses and to human perceptions of environmental quality. Thus, some empirical study of the perceived effects of changes in atmospheric conditions (pollution) in Class I areas seems essential to the implementation of the Clean Air Act Amendments.

It may be that perceptual measures of visibility and of scenic beauty will be closely related. Alternatively, each measure may provide a different type of indication of the effects of man-generated pollutants, one being more sensitive in some contexts and the other a better indicator in other contexts. For the time being, in the face of considerable ignorance about the merits of any of the candidate measures in this context, it seems prudent to delay rejection of any approach and to proceed with parallel studies of all promising assessment strategies. After some information is available regarding the interrelationships among alternative perceptual measures and their relationships to physical/optical measurement systems, an effective assessment strategy can be developed that will facilitate the implementation of the Clean Air Act provisions for Class I areas.

ASSESSING VISUAL AIR QUALITY

Once the question of what to measure has been resolved, the problem of how to measure it may be approached. Whether visibility (indexed in terms of detection, discrimination or some other perceptual task) or scenic beauty is chosen as the basis for visual air quality assessment, types of landscape settings, lighting conditions, and observer characteristics will all be important. If comparable measures are to be obtained for the different Class I areas, uniform assessment procedures will be essential.

The use of standard lighting conditions, observer position, and observer characteristics would provide the best assurance of comparability of indices from one area to another. However, such control over the environment is more readily attained in the laboratory than in the nation's parks and wilderness areas. For some areas the most critical concerns may be for views extending 50 miles or more, while others may offer no views of as much as a mile. Procedures that would be appropriate for measurements over a 50-mile region may not be appropriate for areas extending only a few hundred feet. Matching lighting conditions may be less difficult, but lighting will be affected by atmospheric conditions, thus confounding many comparisons between areas. Getting comparable panels of observers to view and judge 158 different areas ranging from Mt. McKinley in Alaska to the Hawaii volcanoes to the Everglades in Florida could also present some difficulties (although I suspect volunteers would not be that hard to find).

Standardization, then, can at best be approximated and comparability in measures from area to area will likely rely on statistical approximations. This is not necessarily bad. Indeed, there is little reason to believe that any single measure or criterion could ever be rigidly applied to situations so diverse as the Class I areas represent. Considerable flexibility will be necessary, but some standardization of procedures is required if any meaningful assessment of visual air quality is to be achieved.

One means of facilitating standardization and control in the assessment process is to use some indirect representation of the areas (and air) rather than relying entirely upon on-sight evaluations. Color photography has proven very effective in many other studies of perceived environmental quality (e.g., Daniel & Boster, 1976; Zube, 1974). Standardized photo-sampling procedures, implemented by a small number of trained individuals, would be much easier to accomplish than would standardization of actual field observations. Moreover, once appropriate photo representations were available, it would be relatively easy to present photos of many different areas to diverse panels of observers. Viewing circumstances and the context in which the observers make their judgments could also be better controlled. Of course, the validity of photographic representations in this context would have to be established (Daniel, 1976), but methods seem reasonably well developed for accomplishing that task (e.g., Daniel & Boster, 1976). Further, the positive results of tests of the validity of photographic representations for other environmental quality assessments offer substantial encouragement for the application of similar representation procedures in the context of visibility and/or scenic beauty assessments.

When and Where to Measure

The development of a reliable and valid photographic representation method would be an important step toward obtaining comparable measures of visual air quality in the Class I areas. Still, important considerations would remain. Atmospheric conditions, both natural and man-caused, vary widely and change continuously, so the frequency and timing of measurement samples will be critical. Time of day, season of the year, and the occurrence of wet and dry or hot and cold periods can all be expected to affect atmospheric conditions and, thus, visual air quality. Some areas may be more variable in these respects than others, so the frequency (or temporal distribution) of measurement samples required to obtain stable indications of visibility may differ from site to site. Even if samples are taken frequently over a year's time, there is no guarantee that any particular year is all "typical" or that all important atmospheric conditions will be adequately represented.

Similar problems occur in determining where within a given Class I area to make measurements. Some of these areas cover as much as two million acres. Determining which locations, and which of many possible views from each location present representative conditions is not trivial. For the larger areas, it is reasonable to expect that landscape characteristics and man-caused pollution effects will be quite different from one part of the area to another. Thus, any index based on observations made in one region will provide little indication of conditions in other parts of the area.

Because the effects of variations in time are all in effect at every location within an area, the number of different measurement samples needed to represent all of these conditions is a product that reaches staggering proportions. It is obviously not even remotely possible to obtain samples at all of these places and times. Neither can any blind random-sampling process solve this dilemma. Some means of categorizing areas and parts within areas in terms of visually-relevant characteristics must be developed. Then samples of practical sizes can be distributed rationally within each category and some measure of visual air quality can be obtained and assigned to all areas belonging to that category. The basis for determing these categories is not now established. The rules for assignment of areas to categories must, however, adequately reflect the types of views afforded by the different landscape types and the types of atmospheric conditions (natural or otherwise) that occur over them.

IMPLEMENTING CLEAN AIR STANDARDS

To reduce or prevent man-caused degradation of visual quality the effects (atmospheric products) of human actions must be systematically related to visual air quality. In the present context, the effects on Class I areas of emissions from power plants, smelters, and other developments must be determined. Further, these effects must be known in substantial detail, and with high degrees of precision. The visual quality implications of reducing or increasing emissions of a specific element by 10%, or of moving an emitting source 10 miles in one direction or another could be significant. Implementation of the Clean Air Act Amendments will present some very difficult choices, and the more difficult the choice the more precise and reliable the information required for an effective decision.

Visual Air Quality Model

Specifying the relationships between various characteristics of the atmosphere, including natural and man-generated elements in interaction and variations in visual quality requires a theoretical model of considerable complexity. To develop such a model a number of technologies must be combined. Atmospheric sciences must provide some means for determining the composition of rather large, heterogenous bodies of air. This atmospheric assay procedure must allow for rather rapid accomplishment, as the air bodies in question can be expected to change substantially over relatively short periods of time. Knowledge of the physical processes involved in the propagation of light through air bodies must be consulted to determine which characteristics of the atmosphere should be assessed. Some elements that may be found in the atmosphere have little effect on light propagation and others have great effect. Because of the effects on light propagation, the atmospheric assay may need to supplement measures of element concentrations with some indication of how these elements are represented (as gasses, or as suspended particles of various sizes, for example) and how they are distributed. Finally, the sensitivities and limitations of the human visual/perceptual system must be considered to determine what effects alternative light and atmospheric conditions will have on the perception of various types of objects in different landscape contexts.

All of the needed technologists are reasonably well developed, but their application in situations such as those posed by the Class I areas will undoubtedly require additional research and development effort. Further, because each of these technologies has been for the most part developed independent of the others, combining all of them into one interrelated model will require extensions and modifications of each. In short, the ingredients for achieving the necessary models can be summed up by two well worn cliches of contemporary vintage--"more research is needed" and "an interdisciplinary team effort will be required."

Applying the Visual Quality Model

The purpose of developing a model of the type outlined above is to provide a basis for predicting the effects of alternative actions (developments) on visibility in Class I areas. If visibility is found to be below acceptable standards in a given Class I area, the model should assist in the identification of the causes of that visibility impairment. Further, the model should provide a basis for determining what developments must be controlled (and how much) in order to protect natural visual quality in the future.

Applying the model to identify and predict causes of visibility impairment in specific areas requires additional information about visibility impairing substances. If reasonable and effective controls are to be exercised on existing and proposed developments, the types and volumes of atmospheric emissions that those developments produce must be known. Also, the dispersion characteristics of visually relevant emissions must be determined. Often, the visual effects of a particular man-generated element are indirect, resulting from interaction with other man-generated or natural elements. Thus, for the model to be applied effectively to specific situations, the model must be augmented by information about dispersion and other parameters of elements that may be emitted into the atmosphere.

CONCLUSIONS

The visual air quality model, and the approach to its development outlined above, is admittedly ambitious. Considerable information about complex processes is required. Collaboration among disciplines that have previously had relatively little interaction is essential. The context of this effort is not a controlled laboratory, but many highly complex and uncontrollable natural environments that are subject to the whims of weather and the confounding effects of variations in terrain, vegetation, and other factors.

Adding to the above difficulties is the fact that the task itself is not well-defined--what kind of visual quality is to be measured

predicted, and controlled? The motivating legislation refers to visual range and discoloration. But visual range may be defined in terms of detection, discrimination, identification or other measures of how well objects can be seen at various distances. Further, the characteristics of the object to be seen will have important effects on the accuracy (or probability) of perception at a given visual range, regardless of which definition is chosen. Similarly, perceived discoloration may be produced by a large number of factors, only a few of which are directly related to the atmospheric components of the vision system. The effects of changes in visual range and discoloration on scenic quality may not be direct or consistent.

Because of the ambiguity regarding the goals of the Clean Air Act Amendments, the methods and procedures adopted for measuring visibility and visibility impairment will, to a considerable extent, determine the actual accomplishments of the legislation after the fact. This is not necessarily a bad outcome, and it is to a large extent unavoidable. However, such a prospect argues strongly for careful and deliberate development of measurement procedures and predicition models.

In the face of strong motivations for rapid action on a problem as complex as that addressed by the Clean Air Act Amendments, there is a strong temptation to resort to "quick and dirty" methods based on intuitive models. Very frequently, however, such an approach is based upon a large number of arbitrary assumptions and the measures produced have only tenuous correspondences with the real world.

Because of the complexity of measuring and predicting visibility in Class I areas, careful theoretical analyses will play a very important role in any viable approach to the problem. The approach advocated in this paper, however, involves a great deal of interaction between theoretical model building efforts and confirming empirical studies. Direct tests of the relationships between physical/optical and perceptual components of visual air quality are necessary. This approach may be time consuming, but some approach that recognizes the importance of all components of the visual system will, in the long run, prove the more effective means for achieving the goals of the Clean Air Act Amendments.

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Psychophysiological Approaches to Visibility[1]

Roger S. Ulrich[2]

Abstract.--By combining physiology and psychology, psychophysiology can contribute to a more comprehensive understanding of visual landscape perception. Psychophysiological approaches make possible analysis of the effects of different visibility conditions on physiological systems, and insights concerning influences on emotional states. Measures of physiological responses, such as brain waves and heart rate, are valid and sensitive indicators of an individual's arousal level, which in turn is expressive of incoming stimulation from the visual environment. It is likely that clear versus polluted viewing conditions have different effects on arousal. The paper outlines two possible psychophysiological experiments for investigating effects of degraded visibility. As background to the experiments, the concept of arousal is discussed, and a summary is provided of physiological measures that may prove productive in visibility research.

INTRODUCTION

Environmental perception research to date has relied heavily on the measurement of verbal responses, and to a lesser extent, overt behavior. Investigators have paid very little attention to a third important source of quantifiable data concerning perception--physiological responses. This neglect is unfortunate because psychophysiological approaches--that is, approaches combining physiology and psychology--have considerable potential for shedding light on questions of perception and awareness of visual landscapes. Physiological responses (e.g., brain electrical activity, heart rate, blood pressure, muscle tension) are valid and sensitive indicators of an individual's activation or arousal level, which in turn is expressive of the incoming stimulation from the visual environment (Berlyne 1971). Some physiological responses provide valid measures of states of consciousness and alertness (Shagass 1972), and in certain instances are indicative of emotions (Lang, Rice, and Sternbach 1972). Compared to verbal measures, physiological procedures offer the important advantage of allowing continuous monitoring of an individual's responses during an experiment; this enables comparisons of the temporal characteristics of perceptions of, for example, clear versus polluted landscape views. When combined in experimental designs with verbal or psychological measures, physiological procedures can make possible a deeper level of understanding and wider range of inferences. A related point is that physiological findings provide a means for validating results obtained from other types of measures. These comments suggest that the use of psychophysiological approaches in visibility research can contribute to a more comprehensive and sound understanding of the human effects of degraded visibility. It should also be pointed out that compared to studies based exclusively on intuitive or subjective procedures, investigations utilizing physiological or medical measures have been much more successful in motivating governmental action and public concern regarding environmental quality. It is therefore possible that psychophysiological studies of visibility would carry greater weight in planning or regulatory contexts, and prove more effective in terms of implementation.

Although it appears that psychophysiological procedures have not yet been utilized in a visibility experiment, these techniques were applied in a recent investigation of visual landscape perception (Ulrich--in press). In this experiment, student subjects viewed color slides of either (1) nature environments

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dominated by trees and other vegetation, (2) nature with water, or (3) urban environments without vegetation or water. Data concerning the effects of viewing the different types of landscapes were obtained in part from two physiological measures, heart rate and alpha wave amplitude. Alpha is a brain wave that is a valid indicator of activation, and is associated with feelings of wakeful relaxation. A salient finding was that alpha amplitudes were significantly higher when individuals viewed nature dominated by trees and other vegetation, as opposed to the urban environments; similarly, alpha was higher on average when the slides showed water rather than urban content. These findings strongly suggested that subjects felt more wakefully relaxed when viewing the nature as opposed to urban scenes. Although this experiment did not address visibility, the outcome indicates that psychophysiological techniques can provide new insights concerning perception of visual landscapes. The fact that the alpha measure detected variations in the influences of different types of landscape scenes suggests the likelihood that physiological techniques are sufficiently sensitive to be useful in visibility research, and could differentiate individuals' responses to clear versus polluted scenes.

In the following sections, a brief discussion is first provided of a central concept in psychophysiology--arousal. This is followed by a summary of some physiological measures that might prove fruitful in visibility research. The next section outlines two possible psychophysiological experiments for investigating effects of degraded visibility. Finally, general comments are made concerning possibilities for integrating psychophysiological findings with environmental measurements such as visual range.

THE CONCEPT OF AROUSAL

The concept of arousal or activation provides a model for analyzing both physiological and psychological influences of visual landscape perceptions. In general terms, arousal refers to an individual's level of psychophysiological wakefulness, alertness, or excitation (Berlyne 1971). As a psychological dimension, arousal has been conceptualized as varying along a continuum ranging from sleep to frantic excitement (Mehrabian and Russell 1974; Berlyne 1960). As a physiological concept, arousal can be characterized as an indicator of the levels of energy or activity in systems such as the cardiovascular (Duffy 1962). A change in arousal entails a number of psychophysiological changes. For example, if an individual is aroused by a sudden loud noise, his heart rate, blood pressure, and respiratory rate increase, certain hormones are secreted, and brain waves become higher in frequency and lower in amplitude--to list but a few of the physiological changes. Also, he will likely be conscious of feelings of excitement and alertness, and depending on the nature of the noise, may experience some fear or anxiety. The latter emotions would not be produced by activation per se, but rather chiefly by the individual's evaluation of the stimulus or situation. However, it should be pointed out that several investigators have identified arousal as a basic dimension of emotion that plays an important role in defining the feeling state (Schlosberg 1954; Osgood, Suci, and Tannenbaum 1957; Mehrabian and Russell 1974). For instance, according to Schlosberg's framework (1954), the classification of a particular emotional state requires reference to the arousal level. In this view some feelings are characterized by higher arousal (e.g., anger and fear) whereas others, such as calm, are low on the arousal scale. This approach suggests that physiological recordings are useful not only as measures of activity in physiological systems, but can also distinguish emotional states in terms of the arousal dimension. A related point is that some emotions (e.g., anger) are associated with specific patterns of physiological activation, and this provides an additional basis for using physiological data to differentiate emotional states (Ax 1953; Schachter 1957; Lang, Rice, and Sternbach 1972). In a few instances, a particular physiological response in a single system is indicative of a specific emotion. For example, the contingent negative variation (CNV) response, a type of evoked brain potential, is a sensitive indicator of feelings of expectancy (Walter et al. 1964).

Concerning visibility research, it should be emphasized that virtually any change in an individual's environment or stimulus conditions will affect his arousal level (Duffy 1962; Lang, Rice, and Sternbach 1972). This point of course applies to changes in the visual environment. Numerous experiments have established that different types of visual displays, such as random polygons or patterned versus diffuse light, have different activation effects (e.g., Berlyne and McDonnell 1965; Spehlmann 1965; Libby, Lacey, and Lacey 1973). Not surprisingly, recent studies suggest that similar conclusions apply for the case of landscape scenes (Ulrich 1979, in press). It therefore appears very likely that perceptions of clear versus polluted versions of a given landscape have different effects on arousal. In sum, a psychophysiological approach entails measurement of arousal responses, and this makes possible an evaluation of the effects of different visibility conditions on physiological systems, and insights concerning influences on emotional states.

SOME MEASURES AND METHODOLOGICAL CONSIDERATIONS

The techniques used most frequently in psychophysiology record responses in three general systems: the electrocortical, autonomic, and skeletal-muscular. These systems are not perfectly coupled or integrated (Lacey 1967), and arousal responses in different systems occur at different levels and are set into action at varying rates (Shagass 1972). For example, an increase in arousal produced by a visual stimulus will be evident in an evoked potential (cortical system) within approximately 200 milliseconds after stimulus onset, whereas the skin resistance response (autonomic system) to the same stimulus will have a latency of about 2 seconds. Also, in certain instances activation can be evident in one system but not in others. Not unexpectedly, measures of arousal often correlate poorly across systems, and this can lead to complications and ambiguities in the interpretation of findings. In general, however, a visual display or other event that influences activation will be reflected in the results from several physiological indicators, including those measuring activity in different systems. These comments provide a background for Table 1, which lists some physiological measures that would likely be productive in visibility research. The table is by no means inclusive; among the notable omissions are psychoendocrine procedures that entail blood or urine tests (Frankenhaeuser 1975).

If the investigator uses measures such as those in the table, he must pay close attention to several experimental variables that usually have much less importance in designs employing verbal measures. Psychophysiological procedures generally require more standardized or controlled conditions in the experimental environment. For instance, room temperature should be standard because several physiological responses are affected by this variable (e.g., brain waves and GSR). Some control of

Table 1.--Some physiological indicators applicable to visibility

Physiological system	Indicator	Comments
Electrocortical	Brain waves (beta, alpha, theta)	Beta associated with higher arousal and accordingly with states such as anxiety and anger; alpha with feelings of wakeful relaxation; theta with drowsiness.
	Evoked potentials	Sensitive indicator of cerebral arousal to visual stimuli. In order to be measured, necessary to precisely define onset of visual display; this would dictate use of slides or other landscape simulations rather than real views.
Autonomic	Heart rate	A complex response. Strong emotions or mental activity produce heart acceleration. Visual attention to environment tends to produce deceleration; greater slowing associated with greater attentiveness and readiness to take in a visual environment.
	Blood pressure	Cannot be measured continuously
	Respiration rate	Respiration volume also a useful measure.
	Plethysmographic response	Refers to change in volume of a limb or digit resulting from blood vessel constriction or dilation. Sensitive arousal measure that is relatively unaffected by subject movement.
	Galvanic skin response (GSR)	Electrical resistance of skin changes in response to emotion eliciting stimuli.
Skeletal-muscular	Muscle tension	

humidity is desirable, especially if skin resistance is measured (Edelberg 1967). The recording of brain waves (EEG) necessitates an electrically shielded room. Indeed, EEG electrodes are so sensitive that an unshielded light or electric motor in the vicinity of the subject can produce a 60 cycles per second wave pattern in the data and thus ruin the experiment. Concerning subjects, artifacts associated with individuals' movements can be a problem with physiological measures. This would dictate in most visibility experiments that the subject view landscape displays while seated motionless in a chair having armrests. A further consideration in the handling of subjects is that psychophysiological arousal levels can vary diurnally in a marked fashion (Ulrich--in press). Because the individual's arousal level at the beginning of an experiment can affect his responses (Johnson and Lubin 1972), different results may be obtained at different times of day. It is therefore necessary to balance the scheduling of subjects in terms of time of day, or run all subjects at approximately the same hour. The methodological considerations summarized here, especially those relating to the experimental environment, constitute some of the principal drawbacks of a psychophysiological approach.

TWO POSSIBLE VISIBILITY EXPERIMENTS

Within the perspective of the previous sections, the following outlines the salient features of two experiments that could be performed to investigate visibility.[3] Although the designs differ in several respects, both would use the same battery of physiological measures, and in each case the general objective is to differentiate individuals' responses to landscape scenes during clear as opposed to degraded visibility conditions. Degraded visibility is defined here to include atmospheric discoloration as well as reductions in contrast and visual range.

Experiment 1

Compared to most psychophysiological experiments, this design is characterized by simplicity, which would enhance its communicability in decision-making contexts. The essential elements are as follows:

1. Data would be collected in an electrically shielded room having a large window overlooking a high-depth scenic vista susceptible to degraded visibility. The room could be purpose-built, or an existing structure could be modified. A better solution, however, would be to modify a small house trailer, creating a mobile psychophysiological laboratory that could be towed to different sites (Figure 1).

[3]The author wishes to thank Drs. Barry Shmavonian and Monte Buchsbaum for their suggestions concerning the experiments.

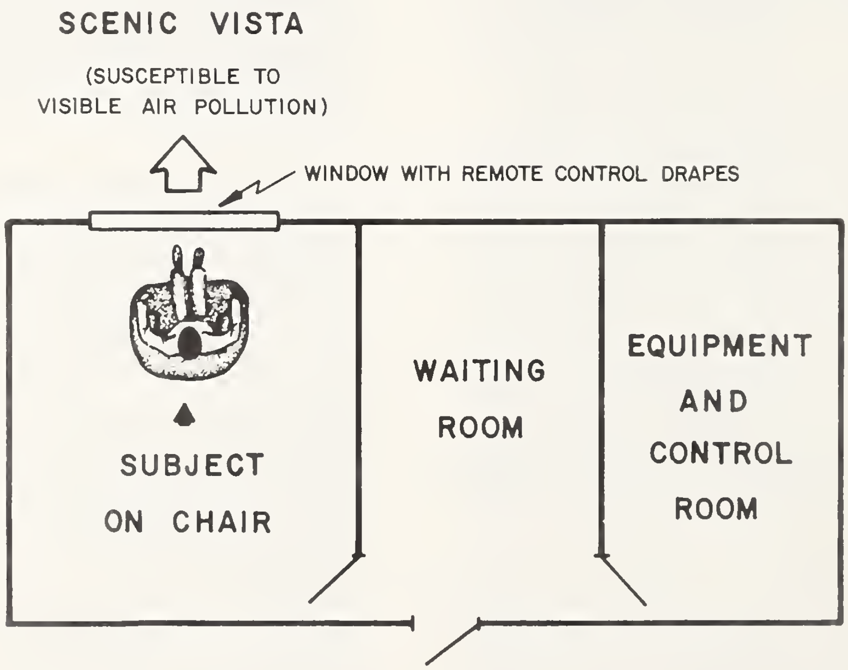

Figure 1.--Mobile trailer laboratory (top view).

2. The sample of subjects should include individuals from both cities and rural areas, and groups who vary in terms of environmental concern. In addition to rural versus urban influences, other adaptation effects could be assessed by comparing a group of vacationers with individuals living in the vicinity of the vista. Subjects should be studied at the same general time of day; this procedure would control for variations in diurnal arousal, as well as changes in the angle of illumination. Half of the subjects would be run during a clear category of viewing conditions, and the remainder during a degraded category. The minimum sample size would be roughly 120-160, depending on the range of visibility conditions studied. An alternative procedure would be to study each subject during both clear and polluted conditions. This would produce sound results with fewer individuals and a smaller total number of trials.

3. Subjects would be run singly; the schedule of procedures for each individual would be as follows:

   A. The subject spends approximately 10 minutes seated alone in the laboratory waiting room. This period would assure greater similarity in skin temperatures and initial arousal states.

   B. An experimenter conducts the individual to the recording room, seats him in a comfortable armchair, and affixes electrodes for physiological measurements. The viewing window is covered. The measures would be brain waves, skin resistance, heart rate, respiration rate, plethysmographic response, and muscle tension.

   C. The subject's physiological activity is measured continuously for 10 minutes with the window <u>covered</u>. This period would allow the individual to adapt to the experimental situation, and to the experience of wearing electrodes.

   D. At the conclusion of the adaptation period, drapes covering the window open, and the subject's responses are measured continuously as he views the vista for 10 minutes (Figure 1). At the end of this interval the drapes re-close, and the subject provides self-ratings of his emotions on semantic scales.

   E. The experimenter enters the room, removes the electrodes, and the session is concluded.

   F. For each session, the experimenter records visibility using both the observer method and a contrast telephotometer.

4. In very general terms, the analysis phase would determine if psychophysiological states varied as a function of visibility conditions. Tests would also be performed to identify possible differences among subjects as a function of rural versus urban background, degree of environmental concern, and socio-economic variables. Findings would be strengthened and broadened if results were also available from ratings of psychological properties of the vista, such as complexity and pleasantness, during different visibility conditions (Berlyne 1971; Ulrich 1977; Kuller 1972).

Variant of Experiment I

The data collection room would have one additional window, allowing analysis of a subject's responses to two views. The laboratory trailer would be positioned to overlook a high depth landscape from one window, and a low-depth setting from the other. The low-depth view would be essentially unaffected by air pollution and could therefore serve as a control. In a departure from the previous procedures, the adaptation period would be followed by a 10 minute period of viewing the close-in setting. After this low-depth exposure, a swivel chair would allow the subject to turn and observe the high-depth landscape. Data from the low-depth scene would make it possible to control for variables such as cloud cover. Also, if results showed that responses were similar for the low-depth condition, but varied for the high-depth scene as a function of visibility, this would further support the validity of findings concerning effects of degraded visibility.

Experiment II

This design is somewhat more complex, and would make possible a more extensive interplay between findings from psyciological and verbal measures. An important feature is that the use of slides as landscape simulations would allow analysis of phasic, or short term, arousal responses.

1. The basic strategy entails exposing subjects under standard conditions to large numbers of color slides of clear and degraded landscapes. This would require assembling a large collection of slide pairs--each pair depicting a given vista in clear and polluted conditions. At the time each slide was

taken, visibility would be measured using a contrast telephotometer, and if possible, the observer method. The slides should be taken during similar sun-angle and cloud cover conditions.

2. A preliminary experiment would be performed using semantic scales, to determine values for each slide for pleasantness and complexity or information rate (Ulrich 1977, in press; Mehrabian and Russell 1974).

3. Selection of subjects for the main experiment would be according to the same criteria as for the first experiment.

4. In the main experiment, each subject would serve as his own control and attend four sessions. In each of the latter the subject would view either (1) slides of landscapes during clear conditions, (2) slides of the same landscapes during degraded conditions, or (3) a single landscape slide presented repeatedly. The session consisting of one slide would serve as a control, and make possible an assessment of the effects of the experimental conditions--independent of clear versus degraded visibility--on subjects' psychophysiological states.

5. Subjects' responses would be recorded continuously during the slide presentations using the same measures as in the first experiment. Also, individuals would provide self-ratings of their feelings both immediately before and after each series of slides (Ulrich 1979).

6. Each subject would be studied at the same hour on different days. Because each individual would serve as his own control, sound results could be obtained with a sample of 50 or less.

7. This experiment would yield a wide range of findings concerning both physiological and psychological influences of degraded visibility. Although methods of analysis are too numerous to list here, it should be noted that examination of some phasic arousal responses might prove of particular interest. For instance, if differences were found in phasic heart rate responses (occurring during the first second or two after exposure) to clear versus degraded views, this would suggest variations in attentiveness and readiness to take in the scenes as a function of visibility (Lacey 1967; Lacey et al. 1963).

AN INTEGRATED VISIBILITY FRAMEWORK

An appealing research goal is the development of a model or framework that integrates statements concerning psychophysiological effects of visibility with environmental measurements such as visual range. The central "if" changes in the psychophysiological responses of a large percentage of people in a given population. This is in fact very likely. If the experiments outlined in the previous section were performed, findings would probably show that psychophysiological arousal is higher for most people when viewing landscapes in clear conditions. This is likely because compared to low visibility conditions, clear views in most instances have brighter, more saturated colors, higher light intensities with more patterning, as opposed to diffuseness, and higher levels of complexity. These qualifies all favor higher arousal (Hogg 1969; Spehlmann 1965; Berlyne and McDonnell 1965). It is also plausible to hypothesize that clear conditions will elicit higher pleasantness, and be more effective in terms of maintaining attention and interest (Ulrich--in press). However, there will certainly be individual differences in responsiveness, and perhaps some variations among large groups in the population. For example, environmentally concerned individuals may respond with anger to polluted scenes, with the result that their arousal levels might be higher initially when viewing degraded rather than clear landscapes. After the initial anger response, however, their attention and interest may wane, and arousal levels might therefore fall rapidly in comparison to viewing clear scenes. If a major difference between the effects of clear versus polluted conditions is in terms of sustaining arousal and attention, temporal changes in psychophysiological states will of course be an important concern in future experiments.

If these hypotheses were borne out by research, one approach to evaluating a given site would be to ask: What increase in pollution will produce statistically significant changes in psychophysiological responses for a majority of individuals in a specified group (e.g., vacationers)? What increase would elicit, for most people, lower pleasantness, less attention or interest over a time period, and lower phsyiological arousal? This approach might be quite sensitive to pollution increments in Western states where visual range is high, but would probably be less sensitive in the East where visual range is comparatively low. Other strategies for an integrated approach to visibility can be suggested, but such discussion is conjectural until experimental findings are available. In any case, there is little hazard in the general conclusion that psychophysiological approaches would considerably enhance our understanding of the human effects of visible air pollution.

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A Suggested Research Approach for Quantifying the Psychological Benefits of Air Visibility[1]

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Abstract.--This paper gives an overview of a research approach that can help quantify the social benefits of air visibility. It is suggested that the expectancy-value approach, from psychology, be used to define and measure specific perceived psychological benefits of specific visibility-related behaviors. Examples of these benefits and behaviors are given. Needs for the proposed research are discussed, including those needs relating to requirements of the Clean Air Act Amendments of 1977.

INTRODUCTION

This paper is concerned with the perceived psychological benefits (PPB's) that might be lost to individuals in our society because of reductions in air visibility (V) by man-caused pollution. Specifically, the paper gives an overview of a research approach that can be used to identify and quantify loss in any such benefits.

V is used "to express the clearness with which objects stand out from their surroundings" (Middleton 1952). Maximum visibility (MV) for a particular location is defined as the highest level of naturally occurring V without any man-caused reductions in V. Therefore, V ranges along a continuum from MV to zero V. At any given location V is determined by the effects of both natural and man-caused influences.

PPB's are defined as the states of well-being which people believe are affected by V. If people feel that reductions in V influence their ability to enjoy a scenic vista, then aesthetic appreciation would be a PPB of V.

NEED FOR RESEARCH ON V-RELATED PPB'S

There are many reasons why considerable research on V-related PPB's needs to be done. First, this type of research is needed to meet the requirements of the Clean Air Act Amendments of 1977. That legislation states that the effect of reductions in V on class I federal lands (i.e., significant natural areas) must be considered when licensing a powerplant or other major point source of pollution. Because one of the major uses of class I lands is recreation, the impact of reductions in V on recreation-related PPB's must be identified. To do this, the PPB's of V-related behaviors, such as wilderness camping, should be identified. For example, our research on the PPB's of outdoor recreation has indicated clearly that nationally significant areas are extremely important to people as places into which they can escape temporarily from many adverse conditions experienced in home and work environments, including the many undesirable effects of air pollution (Driver and Knopf 1976).

The research is also needed because American people are increasingly becoming concerned about the quality of their physical environment. However, deterioration in physical environmental quality (EQ) is seldom perceived as happening suddenly or as attributable to a clearly defined source or cause. Perceived EQ degradation generally happens gradually and interactively. Usually there is a little deterioration in V, a little increase in air pollutants of many types, a little noise pollution, a little water pollution of many types, a few long chain hydrocarbon chemicals or nonbiodegradable substances of one sort or another in small amounts, or a little loss of open space. These little things

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all combine interactively to result in significant perceived reduction in EQ. This could be called "A Theory of Little EQ Things." Of course there are crises explicitly attributable to specific sources and uses, such as when cyanide, other hard poisons, radiation, or Agent Orange, are mishandled or misused. But usually it is the interactive effects of several simultaneous, degrading elements that cause significant environmental deterioration, and cause it to occur slowly, over time.

Because of interactive effects, attention should be given to each degrading element if we, as a society, desire to maintain a quality physical environment. Of course, we should put our scarce research dollars where they will pay off the most. For example, the benefit-cost ratio of this type of research should be compared to the benefit-cost ratios of other types of expenditures. If these comparisons were made, we believe that they would result in considerable economic justification for the research. We also realize that economic justification, although important, does not fully justify research concerning environmental influences impacting human welfare.

Research on PPB's of V is also needed because the current political process does not adequately represent many of those social values. The process is partially inadequate for a number of reasons. First, V is a non-market commodity in that it is not allocated by competitive prices. Therefore, other measures of social benefit are needed. Second, there is no combination of interest-pressure groups which totally represent V-related benefits to all individuals. Frequently, the per capita damage of V reduction is too small to mobilize political action, yet in aggregate these values might be considerable. Even if representative interest-pressure groups did exist, they are seldom adequate in representing all benefits when these benefits are less tangible and multidimensional in nature, as in the case of V-related social benefits. Third, because of air currents, V degradations frequently occur far from the offending source. Therefore, it is sometimes difficult to identify the "major offender." In these situations, affected individuals do not know who the "abuser" is so they feel helpless with respect to the appropriate type of political action to take. Fourth, project development decisions are often made in locations far removed from the place where adverse impacts will occur. This occurs because of air currents and the organizational structure of developers of large industrial projects. Fifth, people sometimes feel that it would make no difference if they did express their V-related grievances in the political process (Nixon 1965). Unless research can identify unexpressed V-related grievances, those values will go unexpressed.

A PROGRAM OF RESEARCH

Research aimed at identifying and quantifying the PPB's of V necessarily focuses on individuals. The reason for focusing on individuals is that despite the fact that many human values are culturally nurtured and directed, the individual still remains the basic decision unit at which social values are formed, processed, and articulated. The individual, too, is the basic unit for aggregating human preferences and values, whether in the quest for a social welfare function, determination of an economic demand curve, identification of the mutual interests of a group, or forging consensus on a political issue. So these individual values need to be identified and measured and then aggregated if the broad social benefits of V are to be quantified.

Drawing on our experience in research quantifying the PPB's of outdoor recreation, we can offer some suggestions for a similar program of research to quantify the PPB's of V (Driver and Brown 1975; Driver 1976a and 1976b; Driver and Knopf 1976; Brown et al. 1977; Hautaluoma and Brown 1978; Driver and Cooksey 1979; and Driver et al. 1979). Such a program of research will be outlined generally. We will begin by briefly discussing some theoretical and methodological issues.

SOME THEORETICAL AND METHODOLOGICAL ISSUES

Two basic questions in value-oriented psychological research are: (1) can beliefs, values, and attitudes (e.g., PPB's) be identified and measured reasonably accurately, and (2) do they relate to actual human behavior if measured? Our answer to both of these questions is yes, if the following conditions are met:

1. The PPB's studied should relate to consequences of behavior and not to objects or things. For example, we should not ask people whether they like or dislike V, but instead attempt to define and measure the PPB's of V-related behaviors. As an example, we could measure the importance to individuals of being able to enjoy a scenic vista or being able to learn about constellations with one's friends or children. The task is to clearly identify all relevant V-related behaviors and their PPB's. Technically, PPB's are called psychological outcomes and the concept was developed from expectancy-value theory in psychology (Fishbein and Ajzen, 1975).

2. The research designs must deal with specific PPB's of specific V-related behaviors. Ideally, the research should not consider general PPB's of specific behaviors, specific PPB's of general behaviors, or general PPB's of general behaviors.

3. The specific PPB's studied must be known, valued, and expected by the persons studied. These PPB's cannot be hypothetical and must be ingrained from past experience or behavior, else the research will be hypothetical. For example, an attempt to define how much a person values being able to see the stars clearly can give suspicious results if, in fact, the person has never seen the stars clearly.

4. In conducting the research, questions must be simple, clear, and accurate so that the respondent understands what PPB's are being measured.

These requirements are based in part on our own research experiences and in part from other researchers using the expectancy-value approach (Atkinson 1964; Vroom 1964; Lawler 1973; Fishbein and Ajzen 1974 and 1975; and Ajzen and Fishbein 1975). Given these requirements, we believe the PPB's of V-related vehaviors can be identified and quantified reasonably accurately. There are problems with different types of bias in measurement, but these problems are not insurmountable. Also, in our focus on individual values, we are aware of the problems of interpersonal value comparison and aggregation (Arrow 1951). Nevertheless, we believe the approach proposed below can provide information useful in allocating V resources.

BASIC STEPS OF THE PROPOSED RESEARCH

Following the above basic theoretical and methodological guidelines, the following steps could be followed to identify and measure the PPB's of V, or the foregone benefits of degraded V, at the individual level:

1. Establish perceivable classes of V for which the benefits will be measured.

2. Define specific V-related behaviors for the different classes of V established in step 1 at particular study locations.

3. Identify the PPB's associated with the specific behaviors identified in step 2.

4. Develop, validate, and apply appropriate psychometric scaling measurement instruments to quantify the PPB's of different V-related behaviors for people with different characteristics in different locations.

5. Search for patterns in PPB's and intensity of benefits across individuals and locations. Test for differences regarding these patterns considering consistency, intensity, and scope of the PPB's measured for the different classes.

Establish Perceivable Ranges in V

Measurement cannot be made at each possible combination of man-caused and natural reduction in V. Therefore, classes of perceivable changes in V degradation must be identified. Alternative approaches to identifying these classes of perceivable changes must be screened as a part of this step 1 research. A methodological issue is whether classes should be site specific or applicable to the entire nation. For example, it might be possible to define 4-6 broad classes of V ranging from 100% V to zero V, with these classes being applicable nationwide. Alternatively, a set of baseline measures might be needed for different study locations as the basis for determining classes of perceivable change in V that are unique to each area.

If it is decided to make the classes site specific, they could be established by having a random sample of persons view a variety of scenes in different study locations under different V conditions. A perceivable change (i.e., what determines a new class) could be defined as that point at which "X" percentage of the people can perceive a change in "Y" percentage of the scenes. To simplify the establishment of classes, research could begin by establishing perceivable changes with MV as the starting point where possible. As the research progresses, the impacts of various combinations of man-caused and natural reductions in V could be investigated.

Obviously, establishment of the perceivable changes in V will be a sizeable research task. Such measurements will need to include color changes in the air as they affect visibility and season of the year effects. Also, the measures could be made both for resident and nonresident populations, especially if the location studied is a popular area for tourists.

Define Specific V-Related Behaviors

Once the above classes of perceivable changes in V are established, V-related behaviors must be identified. Specific behaviors facilitated by MV and constrained by V degradation must be identified at each study location. Again, resident and nonresident populations, and season of the year effects, must be considered.

Defining V-related behaviors is a sizeable research task and beyond the scope of this paper. We can, however, guide thinking a little by suggesting four broad types of V-related behaviors, with some specific examples. The four types are listed numerically below in terms of their relative utility for use in identifying the PPB's of V:

1. Direct viewing or seeing behaviors:

   (a) Attentiveness to scenic landforms.

   (b) Involuntarily scanning of natural areas.

   (c) Viewing night scenes (stars, moon, city skylines, etc.).

   (d) Viewing sky scenes (clouds, blue sky, etc.).

   (e) Viewing specific objects such as in animal study, or physical features such as the St. Louis Arch or the Washington Monument.

   (f) Seeing to navigate (planes, cars, ships, hand gliders, sky diving, wildland orienteering, etc.).

2. Behaviors directly facilitated by V:

   (a) Photography (which might be a type of viewing, but not of the type described above).

   (b) Painting or sketching.

   (c) Sunbathing.

   (d) Not being "cooped up" indoors by a "closed-in" sky. These unconstrained outdoor activities differ from the health-related ones in (e) below in that the consequences relate to moods rather than to health-related fears.

   (e) Engaging in a wide variety of outdoor activities because reasonably high V is mentally associated with unpolluted, healthy air.

3. Passive symbolically cued behaviors:

These behaviors include reading descriptions of scenes or listening to songs that increase pleasure or life satisfaction temporarily because of positive V-related imagery. For example, the song "America the Beautiful" has powerful imagery in the words "from purple mountain majesties above the fruited plain." It just doesn't have the same effect to sing "from purple mountains hidden from view above the brown cast smog!" Or the opening words of "Hello Young Lovers" from The King and I state "When I think of Tom, I think about a night when the earth smelled of sun and the sky was streaked with white. And the soft mist of England was sleeping on a hill. I remember this. And I always will [emphasis added]." These lines imply the need for certain levels of visibility (even to see mist) without which the words would have no meaning. Further, it is interesting how the description of the setting is used to describe a strong sentiment and how both that sentiment and the V-related setting can be captured by those who listen. The PPB's of this listening behavior is symbolic and strongly so by the imagery created. In many ways, music and verse paint a pleasant image of clear skies in one's mind. The titles of, and words from, "Look for the Silver Lining" and "Let the Sun Shine In" readily come to mind. If degraded V were the focus of the words, we speculate that few would listen for long. We also speculate that the PPB's of V-related reading, singing, and listening behaviors are sizable across our nation.

4. Delayed behaviors:

Option demands and existence demands are concepts that economists have coined to define a particular set of behaviors (Tombaugh 1971). Option demands define those options that people are willing to pay taxes to preserve because they plan to exercise that option in the future. Certainly, people wish to preserve the option for a clear view into Grand Canyon. Existence demands are similar to option demands, but the buyer-taxpayer is willing to pay to preserve the existence of something, such as reasonable V in a particular location, even though he never plans to exercise his option to use the good or service being preserved. Both option and existence demands have a wide variety of PPB's associated with them.

These are some example V-related behaviors that research focusing on the individual might identify. As mentioned, such behaviors need to be identified for each of the discernible ranges in V discussed in step 1. After such a comprehensive list of V-related behaviors and behavioral changes is developed, the next task is to identify the PPB's associated with each of those behaviors.

Identify PPB's

Identification of the PPBs gained from V-related behaviors, or the benefits foregone because of degraded visibility constraints on preferred behaviors, is a sizeable research task. It will require many probing conversations with individuals exhibiting different V-related behaviors and much iterative searching so these values can be clearly defined as researchable variables. We will mention only a few possible such benefits for illustrative purposes.

Some of the PPB's listed are quite specific and would be identified only if an extensive research program on the PPB's of V were undertaken.

The benefits of viewing a scenic vista might be aesthetic appreciation; of involuntarily scanning a natural landscape, mental relaxation; of cloud viewing, appreciation of natural forces and gaining a sense of place; of star viewing, nurturing a sense of time and continuity, learning astronomy, or sharing knowledge; of wildland orienteering, achievement and exploration; of photography, status, creativity, and reminiscence; and of sunbathing, status, self-esteem, and enjoyment of the warm sun on the skin. Or outdoor activities under clear skies could lead to feelings of exhilaration, vitality, and openness in one's orientation to their environment rather than depression and gloom. Behaviors of listening to songs or reading verse with V-related imagery could give romantic benefits, sense of pride in one's country, or otherwise stimulate positive-cheerful thoughts that increase life satisfaction.

Apparently, the list of V-related PPB's is quite lengthy. Also, it would seem that some of these benefits are more lasting than others.

Developing Valid Measurement Tools

Once specific V-related behaviors and PPB's are defined, techniques must be developed to measure the relative importance of these PPB's to the individuals affected. Techniques of psychometric scaling and social value-judgment evaluation are available for these purposes.

Because human behavioral research is imprecise, the results obtained by applying the selected measurement technique must be checked for accuracy using as many cross-checking procedures as possible. At a general level, three different types of human behavioral response can be researched. These are verbal, overt nonverbal, and physiological behavior. Each type of behavior implies one or more research approaches. For example, we have proposed the use of scaling procedures and questionnaires to define respondents' preferences for specific PPB's associated with specific V-related behaviors. Other verbal response techniques could include statements of willingness to pay money to prevent reduction in V, or the use of diaries or memoirs to capture psychological values. The research techniques could include observations of behavior such as actual visitation to areas with increasing levels of V impairment, the use of gaming-simulation methods to appraise values, or having respondents sort photos reflecting different levels of V into piles according to some preference criterion. Physiological measures are self-explanatory and relate to those variables mentioned by Ulrich in these proceedings. Many cross-checking techniques should be used to converge onto those V-related values that stand the test of giving similar results across these alternative approaches (Driver 1976b).

Pattern Identification

Once the PPB's are quantified, tests should be made for patterns in these values across people with different characteristics who are experiencing different V-related situations. In that way, we could get a better idea of the social impacts of V reduction, for whom the impacts are the greatest, and the types of impacts (by magnitude, scope, location, etc.) that are the worst. Thereby, we could understand better the social costs associated with V impairment.

SUMMARY

Research on the social values of V must, at least in part, focus on how individuals value V. A proposal for a program of research for identifying and quantifying the PPB's of V and the negative impacts of V reduction has been outlined. That research seems justified on legal, theoretical, economic, and political grounds. The approach described proposed that an attempt be made to identify and quantify specific PPB's of specific V-related behaviors. Five basic steps to that research were discussed.

Obviously, this proposed program of research is difficult and will take time. However, the need for this research is particularly important as our nation changes its energy development programs toward the use of coal. As coal-fired powerplants and other polluting sources increase, trade-offs between maintaining V and gaining the benefits of continued development need to be made. In making these trade-offs, we need the best information possible on both gains and losses.

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Air Pollution, Values, and Environmental Behavior[1]

Ross J. Loomis and Thomas C. Greene[2]

Abstract.--Managers of environmental resources should consider social and behavioral aspects of environmental values as they relate to the air visibility issue. Magnitude values associated with visual quality are dynamic in nature and influenced by a number of factors including perceptual sets induced by media presentations, psychological adaptation and any applicable social values held by observers. Social values, as they reveal how important environmental resources are to different segments of the public, should be measured directly. Such direct value estimates could provide important information to environmental decision makers by anticipating behavioral reactions to both physical environmental conditions and policies instituted to deal with those conditions. Understanding the range of possible environmental behaviors evoked both by pollution, and the policies created to deal with the latter, is also part of the values issue. There is a rapidly growing research literature devoted to understanding behavioral reactions to environmental problems, as well as establishing techniques to influence such environmental behaviors. The use of these behavioral change techniques, however, raises serious social value questions in a pluralistic society. It is suggested that open discussion of both environmental social values and related behaviors is an integral part of the visibility issue, or any other environmental problem.

INTRODUCTION

The following item appeared in the Rocky Mountain News for February 15, 1979:

> "The city of Vail wants residents and visitors to have a smokeless weekend. Officials aren't launching an anti-cigarette campaign, however, this time the target is fireplaces. Clean air is an important part of "the Vail experience," says Mayor Rodney Silfet. Unfortunately, the Vail experience has become a little hazy lately. Vail has 3,800 fireplaces and they are the major source of a brown haze which sometimes fills the Gore Valley, officials report. As a result, they're asking Vail residents and visitors not to use their fireplaces during the three-day Washington's Birthday holiday."

Three important features stand out in the news item cited above. First, the reader must assume that impaired visibility was observed. Very little is said directly about the detection of any visible air quality problem. Second, an emphasis is implied for the importance of experience. It is interesting to note that managers of museums, resort towns, and theme parks, such as the Disney enterprises, are able to state directly the importance of experience. The phrase "the Vail experience" clearly implies that a valuing process has taken place. Critical to that process is that air visibility is regarded as part of the total experience of a particular environment. The third and perhaps most important aspect of the story is that people are actually trying to do something about air visibility. What really matters in the end is not what people say about visibility but what they are willing to do, or not do, to improve visual quality (or keep a level of visual quality that already exists).

[1] Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

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These three features of the news story form the basis for this paper. We are interested in describing some of the social and/or behavioral considerations decision makers, like the officials at Vail, should bear in mind in dealing with the visibility problem. To accomplish this task, a distinction will be made between two definitions for the word value. First, value is used to denote magnitude or quantity and, as a rule, some kind of symbolic unit is designated to represent the value in question. Clearly, much of the discussion at the Visibility Values Workshop centered around such a quantitative or magnitude meaning of value. We will emphasize the dynamic or changing nature of psychological magnitude values used to describe perception of the environment.

The second definition of value we will use refers to social principles or goals that are considered important by individuals, specific groups, or an entire society. We will consider this social meaning of value to refer to a pervasive psychological property of people which is capable of influencing their estimate of magnitude values at any point in time. In fact, it is our position that magnitude value estimates of visibility will prove rather pointless without indicators of relevant social values held by observers. Thus, it becomes necessary to measure social values in as direct a manner as possible.

Obviously, these two definitions of value do not exhaust the pool of connotations associated with the word. In fact, the Second College Edition of Webster's New World Dictionary provides no fewer than thirteen definitions. More than one of the thirteen definitions contains a reference to an economic or utility connotation. Since this interpretation of value is amply covered in the contributions by Randall and Brookshire to the Proceedings, we will make only passing mention of the utility function of value.

The third feature of the news story, environmental behavior, will make up the last section of this paper. Both magnitude and social values can provide approximations of what behaviors people may use to cope with an environmental problem like air pollution. Knowledge of potential reactions, and more specifically, the application of any such knowledge, raises additional questions about social values. It will be our position that such questions must be raised to fully understand the visibility values issue.

THE DYNAMIC NATURE OF MAGNITUDE VALUES

It is tempting to think of any magnitude value as a discrete point on a scale of continuous points. If such were true, it would be possible to determine what level of atmospheric discoloration, for example, most people are sensitive to and define visual impairment as a value at that point or greater. Unfortunately, things are not that simple. Human observers have a way of mixing together judgments of absolute environmental properties with what we might call "error." Error refers to other psychological variables that influence the actual judgment made by an observer. To an engineer, error might be synonomous with extraneous noise in a system. Modern psychophysics has numerous methods for determining error and controlling the contribution of error to absolute judgments. From a practical standpoint it may be of limited utility to think about judgments of visibility free from error. It is not too likely that a visitor taking in a vista at the Grand Canyon is very worried about performing a technically correct psychophysical judgment. He or she will mix together both error and absolute judgment. In the final analysis, both absolute and error components are part of the magnitude value estimate. We should <u>expect</u> perceptual error and incorporate it into any discussions of magnitude values.

Daniel's contribution to these proceedings provides more comment on the complex and dynamic nature of environmental perception. We will emphasize here the distinction between threshold and detection estimates of magnitude values. This distinction is made quite clear in a study of odor perception by Berglund, Berglund, and Lindvall (1974). These authors begin with the observation that environmental problem stimuli are often weak or subtle in their nature. Air pollution, the gradual build up of litter, or the steady increase of noise associated with urbanization all occur over time and may involve only subtle change on a day to day basis. Berglund et al. studied air pollution in the form of odor associated with automobile traffic and hog farms and found that signal detection provided a better paradigm for measuring sensitivity to odor pollution than the traditional model of absolute threshold.

Signal detection theory (Tanner and Swets, 1954) does away with the idea of absolute threshold and postulates that perception of an environmental stimulus is a matter of correctly detecting a signal against a background of noise. Both the signal and background noise are seen as distributions of magnitude values that can fluctuate over time and between individuals. Noise includes not only physical stimuli extraneous to the signal, but also neural activity within the observer. Perhaps the most important thing about detection theory is that it considers noise or error as part of the perceptual process and can demonstrate perceiver judgments both with noise

present and also measure absolute magnitude judgments with noise controlled for. Berglund et al., therefore, were able to generate data on odor strength that are relatively independent of psychological variables such as social values (observer bias).

What are some possible variables that could contribute to perceptual error in the detection of visual quality? We will examine three candidates of potential error or noise variables. One important area of study in magnitude value research is the determination of just which extraneous variables are important in observer judgments or environmental quality. Our candidates are perceptual set created by media exposures, psychological adaptation, and relevant social values held by the observer.

Media Perceptual Sets. Craik (in these Proceedings) has called attention to instructional sets or preparations that can alter how one perceives a particular setting. We would like to expand this idea to include general perceptual sets created by media presentations. Barker (1976) concluded that media presentations are actually dominant over direct sensory observation of air quality. For example, in a study of observer appraisals of air pollution in two communities with comparable physical conditions, observers in the one community that had extensive media coverage informing residents of the "good" air quality reported less concern with air pollution (I. G. U. Air Pollution Study Group for the U. D., 1972, as reported by Barker).

Media influence could work to change magnitude value estimates either way. Messages proclaiming that air quality is not a problem could decrease sensitivity, as in Barker's example. Where Class I lands are involved, it may turn out that media induced sets will work in the opposite way. Extensive media coverage proclaiming the deterioration, no matter how slight, of Class I lands could cause observers to use more stringent standards, and increase their sensitivity to visual impairment.

Psychological Adaptation. Environmental stimuli that remain constant, or change very slowly, become familiar and observers tend to habituate or adapt to them. Something must change in a perceptable manner, or a new stimulus appear, to draw anew our attention to that part of the environment. Sommer (1972) speculates that people may be relatively insensitive in their magnitude estimates of air pollution present because increased amounts of visible pollution have accrued gradually. We are talking here about resident observers who adapt to growing levels of air pollution on a day-to-day basis.

Since air pollution in Class I lands is apt to be perceived by a changing audience of travelers and recreationists, two alternate hypotheses come to mind. One hypothesis would suggest that visitors to Class I lands will be more sensitive to pollution since they will rely on absolute magnitude value judgments of what is in the air and not be influenced by psychological adaptation. Visual pollution would have the property of a novel stimulus and catch their attention. A rival hypothesis would be that visitors will be less sensitive to impaired visibility because they have adapted to heavy amounts of visual pollution in their home community. Craik (these Proceedings) suggested this alternative hypothesis when he sounded a caution about using visitor return rates as an index of their perception of environmental quality of Class I lands. Extensive levels of urban pollution might serve as such powerful anchor or comparison points that visitors will be slow in detecting the deterioration of air quality in recreation areas.

Whatever the outoome between the above rival hypotheses, psychological adaptation underscores the importance of the theory of "little things" discussed by Driver, Rosenthal, and Johnson (these Proceedings). Much pollution happens a little at a time and involves specific changes that are not that disturbing if taken one at a time. Adaptation may reduce the magnitude value estimation of impairment on environmental quality. It is important not only to make estimates of how much adaption contributes to error or noise, but also perform magnitude value measurements with adaptation controlled for, to the extent such control is possible.

To a certain extent, adaptation brings some stability to the very dynamic state of magnitude value estimations. However, observer adaptation may be at a level quite different from an absolute judgment of perceived environmental quality. Observers may even adapt to the media messages intended to increase their sensitivity to environmental pollution. It is not surprising, in the light of psychological adaptation, that frequent media announcements of air pollution "alerts" are met with indifference by residents. Such indifference seems to be a part of general adaptation to warnings about environmental hazards (Kates, 1976).

Social Values. Swan (1970, 1974) made a very important point when he noted that overall value systems held by many in society could influence perception of air quality. He suggests that the overall value of materialism is behind much of the environmental crisis facing society. A lifestyle is highly valued because it produces goods and commodities even though

at a high cost of environmental resources. Observers that value a material based lifestyle may view environmental quality much differently than those who feel meditative or "inner experiences" are of great importance (Swan, 1974). Specific values, such as the importance attached to outdoor recreation or preserving nature in a "pure" state could also influence how one makes magnitude judgments of environmental quality. Because various social values are themselves subject to change, fads, fancies, etc., they could contribute to changing estimates of the magnitude of pollution present.

What we are suggesting, and will elaborate on further in the next section, is that social values are analogous to noise in a detection paradigm and are a continuous or pervasive factor in environmental perception. There is a need to study this source of noise or observer error directly and determine its overall importance in the assessment of impaired visibility.

To briefly summarize, the outcome of error or noise variables in perception would be to render judgments much more susceptible to temporal changes. A visitor's judgment of a Class I area may be influenced by something he/she heard on the car radio while traveling to the area. Another visitor might use his/her memory (or pictures) of what the vista looked like on a past visit as a point of reference. Still another observer could employ a more absolute standard of visual quality based on his/her concern that environmental quality is deteriorating and the fact that he/she values preservation of Class I lands. The dynamic nature of magnitude values must be considered along with technical scaling problems, as discussed by Latimer and Henry in their presentations to the Workshop.

THE DIRECT MEASUREMENT OF SOCIAL VALUES

In our opening example of smoke pollution in a resort community, we mentioned that some process of determining the value of good visibility went on, at least in the minds of Vail city officials. To their disappointment, Vail officials may discover that residents place more value on having fires in their fireplaces and will ignore the request to limit burning. It is interesting to speculate if Vail residents even share the same magnitude values as to the undesirability of visual smoke. The value process refers to the ability of individuals to assign relative importance and preference to objects or events in their world and to live with these assignments for prolonged periods of time.[3] Furthermore, individuals are often aware that they hold certain values in concert with others, which gives value a more sociological or societal meaning.

In this section, we will advocate the direct measurement of social values as an important point of information in understanding observer responses to environmental quality. Knowing something about the social values held can provide estimates of social value contribution to the observer error mentioned earlier. Social values can be measured at a global or very general level or be defined in terms of specific preferences. In addition, different values are sometimes combined into a system (Rokeach, 1973). We will discuss examples of both global and specific value measurement and also mention some other considerations about social values.

Measurement of Global Values. It may be possible to relate global social values to specific reactions towards environmental problems. For example, Hummel and Loomis (1978) developed value scales for the importance of materialistic versus inner experience lifestyles. Subjects who favored materialistic lifestyles attached importance to gaining wealth and material goods while those who valued inner experiences felt being well read and seeking solitude experiences were very important. These value scales were suggested by Swan (1974) and Leff (1978). In general, respondents who scored higher on the value materialism scale were less concerned about air pollution and favored major use of automobiles and high energy consumption amenities even at the cost of greater air pollution. Those who valued a lifestyle emphasizing inner experiences were more concerned about air pollution and willing to engage in activities that would reduce energy consumption.

While the Hummel and Loomis work was only a pilot study, their results were consistent with a more extensive value comparison study reported by Rokeach (1973). Employees of a large oil company (specifically salesmen and service station operators) valued individual achievement, material success and comfort along with hedonism more than a national sample of

[3] There is an extensive controversy over the definition of social value as well as how to distinguish values from attitudes, concerns, preferences, psychological benefits, and a host of other terms. We have opted to spare readers from what some might feel to be an exercise in semantic pollution by using value in a rather generic sense as typlified by dictionary definitions. A detailed discussion of the definition of social value can be found in Rokeach (1973).

adult Americans, and having a world of beauty less than the national sample. Direct measurement of global values can provide objective documentation of differences in values that reflect directly on environmental issues.

Measurement of Specific Values. Measurement of more specifically defined values (or attitudes and preferences) can complement estimates of global values like materialism or inner experience. Driver, Rosenthal, and Johnson provided a concrete example of how such research could be done in their contribution to this volume. Note that preferences mentioned in their paper are quite specific to recreational experience. As these authors suggest, there may be a greater likelihood of predicting behaviors associated with values by using more specific statements of preferences.

Systems of specific value preferences, say for the use of recreation lands, could be measured and translated into a more general index of perceived desirability of settings under different conditions of pollution, availability of resources, etc. From such combined measures, it could be possible to compare different environments in terms of perceived benefits and costs associated with each setting. For instance, Cooksey (1978) asked a sample of college students to indicate how important it was to include and exclude certain experiences (e.g., physical effort, spending money, escape from pressures) in their use of possible student leisure-time environments (e.g., home, roadless wilderness, gymnasium, parks). Cooksey was able to calculate a ratio of perceived rewards (included experiences) to costs (excluded experiences) for each environment. Displayed in Figure 1 is the pattern of reward/cost ratios for two subjects. Note that the two subjects differ in how clustered or scattered the distribution of ratios are for the ten recreation settings.

The reward/cost ratio comparison of settings is based on Helmreich's (1974) work with crews that inhabit high risk environments such as space ships and submarines. Helmreich has observed that crews are willing to tolerate high costs in order to experience a setting they value as high in rewards. An interesting assumption of both Helmreich's and Cooksey's thinking is that environmental costs can be perceived independently from rewards. It would be feasible to modify the Cooksey research to include costs related to impaired visibility and other aspects of Class I lands. Visitors, as well as samples of the general public, could be asked to consider using Class I areas when visibility impairment is listed as one experience to be included or excluded. It is also possible from this research paradigm to obtain estimates of how important it is to include or exclude specific experiences.

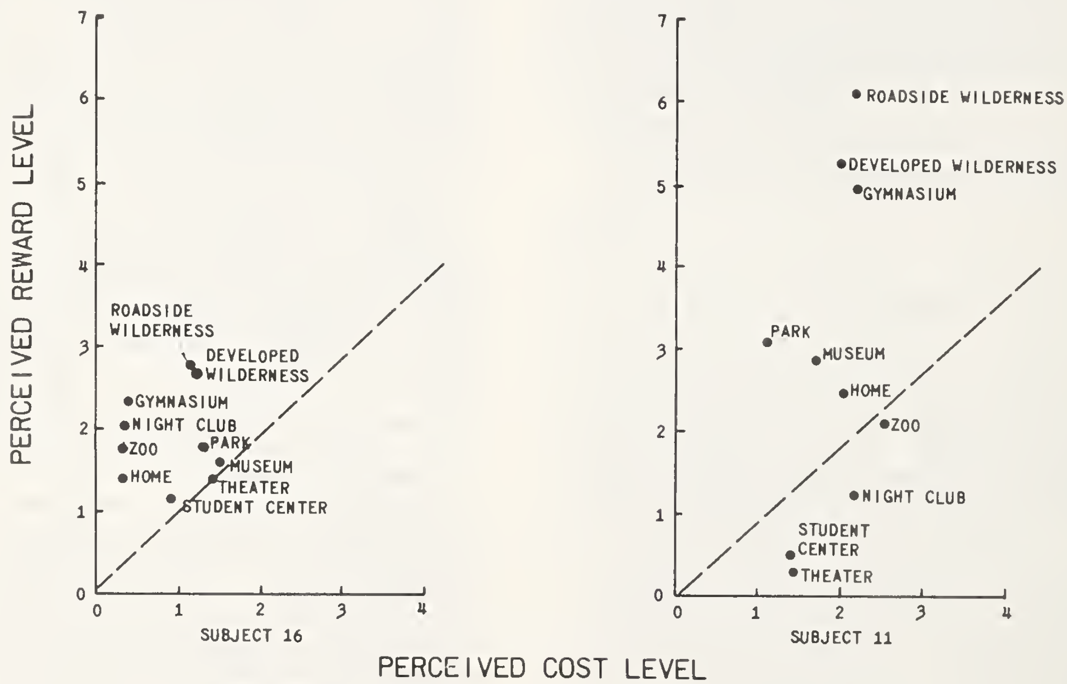

Figure 1.--Perceived costs and rewards of experiences associated with 10 different environments as evaluated by two different subjects. Diagonal line represents a balance of rewards to costs (adapted from Cooksey 1978).

Some Additional Considerations About Social Values. Two specific research efforts are needed to make social values related to environmental issues more useful to resource managers. First, both global and specific values need to be reported through indicators that can measure current value orientations and translate such measures into magnitude type values useful to decision makers. The quality of life indicators proposed at the Airlie Symposium dealt with social values to some degree (Environmental Protection Agency, 1973). Certainly, the Perceived Environmental Quality Indicator described by Craik (these Proceedings) has the potential for including social values as part of environmental assessment. Finally, as suggested in Peterson's Proceeding paper, public surveys and opinion polls can provide indicators of values. It is fairly common to dismiss opinion polls as trivial and often misleading. Properly done, up-to-date surveys or polls are an extremely important tool in a pluralistic society and a form of social invention too easily taken for granted (Platt, 1969).

A second research effort would center around investigations designed to relate social values to magnitude value estimations. The signal detection paradigm mentioned earlier could be used to establish such a relationship. Differences in social value orientations, as measured by either global or specific value measures, could be correlated with how subjects judge the attractiveness of vistas with different levels of visual impairment present. For example, it would be interesting to see how the two subjects of Figure 1 would judge the quality of scenic wilderness vistas since one subject associated much more reward with roadless wilderness settings. Driver, Rosenthal, and Johnson suggest in their paper another possibility for combining social and magnitude values.

One last important consideration about social values should be emphasized. Social value and value systems are subject to change. While change of social values may not have the dynamic or temporal change characteristics mentioned earlier in relation to magnitude values, it is reasonable to expect social values to change over time (Rokeach, 1973). In fact, the environmentalist movement of the seventies is an example of social value change. Economic change and finite limits to environmental resources are bound to bring changes in social values, both in global value systems and specific value topics (Schumacher, 1973). Direct measurement of social values that relate to environmental resource management will be needed to determine the direction as well as implications of value change. It is possible that future American value systems may emphasize quality or experience (including outdoor recreation and enjoyment) over the materialistic pursuits of today (Heilbroner, 1974). If such a shift in values occurs, it may well be accompanied by greater public demand to preserve Class I lands in as Pristine a condition as possible. Furthermore, such a value system might be held by a broad cross section of Americans, in part because of the capacity of modern media to make remote situations seem more immediate.

VALUES AND ENVIRONMENTAL BEHAVIOR

Vail officials valued visibility enough that they were moved to do something. While the exact relationship between values of attitudes and behavior is unclear and debatable (see O'Riordan, 1976; Rokeach, 1973, & Driver, et al. in this volume), we will take the common sense position that values held in sufficient importance do influence behavior at some points in time. Environmental resource managers must live with the fact that any intervention will impact on the social values of those people involved. There are specific behavioral intervention techniques that could be used and we will mention a few of these. In addition, there are potential behavioral consequences that can result from environmental change and/or intervention. Finally, the entire concept of behavioral intervention raises some social value issues.

Behavioral Techniques and Intervention. Leaders in Vail have other options of intervention than simply appealing for voluntary action. There is a growing literature devoted to behavioral techniques which could be part of environmental problem intervention (see, for example, Cone & Hayes, 1977). Four techniques are summarized in Table 1. An example of research on each technique is also provided in the table. We should emphasize that research is limited, and specific techniques often restricted to one or two problem areas. Vail officials could use prompts or reminder messages to keep residents conscious of the visibility problem: Prompts (i.e., well written messages strategically timed and/or placed) would be especially helpful if some type of staged or rationed use of fireplaces is attempted. Social approval and recognition of individual commitments to voluntary restrictions can also be used to encourage participation. Feedback or information about outcomes of reduced fires could also be effective. In the Vail situation an obvious feedback would be clearer skies. Some pollutants are not easily detected by sensory receptors and feedback in the form of media messages, etc. could be tried. Finally, the Vail city fathers could institute positive incentives, like a public celebration festival, to encourage participation. Ideally, improved visibility would be a positive incentive in and

Table 1.--Examples of possible behavioral intervention techniques resource managers could use to deal with the Vail visibility problem

Technique	Reference
1. Use planned prompts to remind and encourage residents to restrict fireplace use	Hayes and Cone, 1977 (a)
2. Provide social approval and recognition for individuals who comply to requests for restricted use of fireplaces	Stern, 1979
3. Provide feedback on progress in improving visibility quality as a function of voluntary cutbacks in fireplace use	Hayes and Cone, 1977 (b)
4. Provide some type of positive incentive for compliance with restricted fireplace use	Schmidt and Ulrich, 1969

of itself if Vail residents share a value of scenic beauty. Disincentives, such as making it harder to obtain firewood, fines for using fireplaces, and a tax on firewood, could also be used. These four techniques are only examples of ideas coming out of this research area.

Potential Resistance Reactions to Interventions. The current plethora of appeals and programs intended to deal with environmental problems has also brought about concern over reasons why people resist or fail to participate. Examples of some of these reactions are displayed in Table 2. The use of prompts, or other appeals, may encourage reactance where people openly oppose or simply fail to respond to appeals. There is some evidence that reactance is accompanied by perceived loss of control over one's life and a sense of helplessness. Behavioral reactance may be intensified if appeals only emphasize problems without suggestions for specific actions.

There is evidence from research on energy conservation programs that people may resist taking action if they feel demands will result in unequal costs to individuals. Some Vail residents may resist complying with a fireplace ban because they do not think it will be equally enforced with people who have wealth and/or status.

John Platt's (1973) paradigm of a social trap describes another kind of reaction. In spite of receiving information about undesirable long term outcomes, individuals may persist in immediate short term behaviors that contribute to the long term outcome. This paradigm has very real application to environmental problems created by short term lifestyle decisions that contribute to pollution. Vail residents may find it difficult to forego a cozy fire even though they know about the smoke pollution. Habits can be hard to break, and simple immediate pleasures are not always easy to give up. While Edney and Harper (1977) confirm the difficulty of breaking up a social trap, they also observed that open communication about long term consequences did lead to some gain in responsible decisions.

Finally, the alternative proposed in an appeal may simply not be acceptable. Vail residents could react by thinking that elimination of fireplace use is inappropriate considering the effort and expense they must exert to enjoy the recreation setting. Perhaps, this reaction, more than any mentioned, points up a conflict in values that can occur between lifestyle preferences and environmental protection.

Social Value Concerns With Behavioral Intervention. To generate information about magnitude and social values and not consider behavioral implications of environmental problems and policies is really to avoid part of the problem. Even a policy of doing nothing about impaired visibility in Class I lands is a response to an environmental problem and will result in reactions from at least some segments in the public. The resource manager is trapped into considering behavioral implications of how the public perceives and values changing environmental conditions.

Our position is that direct measurement of social values can provide important information for considering behavioral implications and the feasibility of using specific intervention techniques. Decision makers need to know how people value both environmental issues and also possible intervention strategies intended to deal with those issues.

Table 2.--Examples of possible reactions to appeals and interventions intended to improve Vail visibility

Technique	Reference
1. Residents may perceive loss of freedom and control, thereby refuse to comply with requests (psychological reactance)	Reich and Robertson, 1976
2. Residents may fail to comply because they feel restrictions are not fairly distributed	Hummel, Levitt, and Loomis, 1978
3. Residents may persist in fireplace use because they perceive only immediate short term gains (social trap analog)	Edney and Harper, 1978
4. Residents may fail to comply because they perceive the request as demanding changes in behaviors they think are essential	Pirages and Ehrlich, 1974

The suggestion of combining behavioral techniques with intervention often raises some major value issues. People are apt to be concerned that efforts to deal directly with significant environmental behavior impose too much control over individuals and violate the right of persons to give informed consent. In fact, the four reactions described in the previous section mirror some of the value issues. Reactance probably is related to values of individual freedom and self-determination, while concern over inequities caused by environmental decision making reflects a concern with equality or fair treatment. Both social trap reactions and resistance to an unacceptable alternative raise questions of value conflict or resentment of having specific values imposed upon individuals.

There are some ways of dealing with the broader value issue of intervention strategies that consider environmental behavior. First, social values should be emphasized more in measurements of public concern (or lack of concern) about environmental issues. Value assessment needs a more equal emphasis with specific opinion polling or attitude surveys. There needs to be a greater emphasis on the value conflicts entailed with environmental issues and possible solutions. Second, environmental decision makers need to be less concerned with influencing public opinion or changing attitudes and more interested in providing forums to exchange information about environmental values and conflicts between different value systems. The term "values clarification" has been used in some situations (e.g., formal educational settings) to describe a deliberate effort to create a process of value discussion. Finally, surveys, opinion polls or voter referendums can be used to estimate the acceptability of intervention techniques. A more open discussion of intervention could evolve into a collective form of implied consent to deal with the value question of using intervention strategies that entail behavior change.

SUMMARY

Our summary will be in the context of the work session in the Visibility Values Workshop that required participants to anticipate information needs of land managers when a visibility problem was under review. A critical aspect of that requirement was the fact that review periods are typically only for sixty days. Information must be readily available under such a time constraint. From a resource manager's perspective, research on visibility values should generate a series of indicators, or research outcome statements, that could provide significant information useful in a review decision. Assuming that research will be able to produce such information, we would suggest the following groups of indicators:

1. Physical Condition Indicators. Environmental quality indicators consisting of physical measures really fall outside of the scope of this paper (see Malm's contribution to these Proceedings). However, it is obvious that such indicators are part of the necessary information pool. In the example used in this paper, smoky conditions at Vail, it is important to note that a technical report (Howard & Fox, 1979) called attention to fireplace smoke as a specific contributor to pollution. Physical data even pointed to a particular lifestyle behavior, that contributed to peak levels of air pollution, namely, heavy use of fireplaces on Friday evenings which marked the start of a ski weekend.

2. Magnitude Value Indicators. Estimates of perceived environmental quality should be provided in a manner that suggests the possible contribution of error variables such as media perceptual sets, adaptation, and personally held social values. Managers need to know whether or not reported values are of long time duration or subject to rapid change. In the case of Vail, magnitude value indicators may be of most importance in determining some arbitrated level of fireplace use that reflects a compromise between total bans and severely impaired visibility.

3. Social Value Indicators. The Vail fireplace smoke example presents an interesting problem in social values since it can be both a source of visual pollution and also a positive aesthetic experience. Measurement of social values would help managers determine just which perception of fireplace smoke is more important to recreationalists. Social indicators may also provide information about the acceptability of any appeal to ban fires, and help managers anticipate possible reactions.

4. Indicators of Environmental Behavior. Since there is just now a growing body of research on how people react to environmental problems, it is not possible to think of this topic as a direct indicator form of information. Hopefully, research efforts will eventually provide decision matrices that can summarize the alternative reactions that could be expected. A broader value issue is the use of knowledge and/or techniques of influencing environmental behavior as a means of coping with problems like pollution. In a pluralistic society, procedures such as voter referendums and value clarification forums may be necessary not only to determine the importance of an issue, but the acceptability of means for coping with the problem.

The physical indicators (number one) mentioned above may be better able to account for significant portions of the variance than the psychological and/or social indicators of points two and three. Therefore, it is well to consider any indicators of magnitude and social values as tentative suggestions of possible decision alternatives. As research results become available it will be possible to firm up the feasibility of specific decision alternatives. Whether or not major research on magnitude and social values related to the visibility problem ever gets done is open to question. Of less question is the fact that visibility impairment problems will be around for a while, and probably become more chronic.

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The Place of Perceived Environmental Quality Indices (PEQIS) in Atmospheric Visibility Monitoring and Preservation[1]

Kenneth H. Craik[2]

Abstract.--The conceptual framework for perceived environmental quality indices is applied to identifying and measuring visibility quality and impairment. On-site context-pertinent observer judgments offer a basis for the implementation and long-term monitoring required by the Clean Air Act Amendments of 1977.

In 1975, the Environmental Studies Board of the National Academy of Sciences-National Academy of Engineering issued a report, Planning for Environmental Indices (NAS-NAE, 1975) which identified the need for a state-of-the-art appraisal of the development of environmental perception measures that can serve as environmental quality indices. During the spring of 1975, a series of research workshops supported by the National Science Foundation was held at the University of Massachusetts at Amherst. A subsequent volume based upon the workshops appeared in 1976, offering a systematic research agenda dealing with: 1) the development of observer appraisal systems for environmental quality, 2) a conceptual model of the observer appraisal process, and 3) a conceptual model for application of operational systems using Perceived Environmental Quality Indices (PEQIs) (Craik & Zube 1976).

My comments on the issues posed by Section 169A of the Clean Air Act Amendments of 1977 are inspired by my own interpretation of the conceptual framework that emerged from the Amherst workshops. The presence here of two contributors to the PEQI workshops, Terry Daniel (1976) and George Peterson (1976), will ensure that other interpretations of those proceedings will be heard. In Section 169A, Congress established as a national goal the "prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from manmade air pollution." Visibility impairment is defined in the Clean Air Act as including reduced visual range and atmospheric discoloration in the vicinity of scenic views in national parks, wilderness areas and other Federal Class I lands. The legislation conveys the sense that a mountain or butte remaining merely detectable is not sufficient, if its clarity is obscured by manmade pollution. Finally, my observations are also guided by the provocative list of conundrums posed by Douglas Fox and Ross Loomis in their memorandum to workshop participants.

I. Perception of Pollutants Versus Perception of Amenity Attributes of the Atmospheric Environment

One of the three Amherst workshops dealt with perceived quality of air, water and sonic environments (the other two focused upon scenic and recreational environments, and residential and institutional environments, respectively) (Craik & Zube 1976). In that session, an important distinction was made between two kinds of indices: indices based upon the perception of amenity attributes and indices based upon the perception of pollutants. The first would constitute a Perceived Environmental Quality Index (PEQI); the second can be termed an Observer-based Pollution Index (OBPI). They display notable conceptual and methodological differences.

In the case of Observer-based Pollution Indices (OBPIs), the core of the construct being measured is provided by scientific, medical and economic formulations of the physical constituents of air pollution, for which various candidates as standard indices have been advanced (e.g., MAQI, PDI, ORAQI). The role of OBPIs is to determine the extent to which observers are able to detect the presence and strength of

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the various physical components of indices which have themselves been derived on the basis of public health and economic considerations. Thus, an OBPI is not a primary index of environmental quality but is linked to a physical index, to which it may accurately or inaccurately relate. One function of OBPIs, as Peter Flachsbart shows in his report, is simply to gauge the extent of congruence between perceptions of pollution and the physical EQIs. It is recognized, of course, that certain physical components of these indices are not perceptually detectable by human observers. Thus, discrepancies between on-site OBPI and ORAQI readings might suggest:

1) eventual problems in the credibility and consequent public acceptance of physically based EQIs;
2) problems of misunderstanding and misinterpretation, calling for programs of public environmental education; and
3) a challenge to scientific understanding of the relationship between OBPIs and the standard physical EQIs based upon scientific-technical judgments regarding health and economic consequences.

And indeed the tradition of research on perceptions of air quality has tended to highlight discrepancies between laypersons' definitions of air quality and the scientific-technical definitions (Barker 1976).

However, the thrust of Section 169A of the Clean Air Act Amendments of 1977 appears to move in quite a different direction. In Section 169A, the focal criteria of quality are directly experiential, with an emphasis upon the clarity of detail in vistas, the range of visibility, and the absence of discoloration. Thus, the measurement approach seems to call for a form of Perceived Environmental Quality Index.

II. Perceived Environmental Quality Indices and Section 169A

A truly comprehensive assessment of environmental quality would include an appraisal of the quality of the environment as it is experienced. Appreciation of this perspective has led to efforts to develop observer-based evaluations of the everyday physical environment that would constitute an array of monitoring indices parelleling the physically-based system of indices based upon public health and economic consequences.

One justification and potential use of PEQIs is their assessment of aspects of environmental quality that intrinsically involve the interplay between the human observer and the environment (e.g., noise pollution, scenic quality). A second function of PEQIs is to serve as criteria for establishing physically-based guidelines and indices. Thus, for example, the hunt is on for attributes of land form and land use that will predict observer evaluations of landscape quality. As I read the intent of Section 169A, its core is preservation of the visual quality afforded by experience of the scenic resources of the Class I lands.

In the context of OBPIs, the observer is explicitly or implicitly asked to estimate a specific physical EQI (e.g. ORAQI). Subsequently, the functional validity of the estimates can be appraised and, if systematically arranged sites have been presented, the specific components of the physical EQI that have served as cues for the observer-derived estimates can be identified. In this approach, the central criterion remains an a priori physical EQI. In the PEQI approach the direct experience-based judgments of environmental quality made by observers constitute the central criteria of the analysis. Subsequently, a search for physical correlates of these judgments can be undertaken, and physical models can be attempted.

III. The Development and Application of PEQIs

In the Amherst workshops, certain critical steps were identified in the development and application of PEQIs.

A. Conceptual analysis.

Psychological measurement procedures begin with the construct to be measured; yet insufficient attention has been devoted to analysis of the basic constructs of perceived quality for the several environmental domains. As understood by laypersons and experts, what is entailed by the constructs of perceived urban quality, perceived natural quality, perceived residential quality, perceived air quality, and so on? Zube and I have subsequently proposed a two-step process in the conceptual analysis of experiential quality of environments: first, compile systematically gathered case studies through interviews exploring the meaning of environmental quality for a particular setting (e.g., coastal, mountain, desert) as a means of nominating an array of experiences afforded by each type of setting and, second, have these potential indicators rated on their prototypicality for a setting and on their importance for evaluations of environmental quality. The category of coastal experience, for example, may be cognitively structured into prototype (clearest cases, best examples of the category, instances par excellence) and non-prototype members, with the non-prototype members tending toward an order from more to less fitting examples (Rosch, 1975; Rosch & Mervis, 1975; Rosch, Simpson & Miller,

1976). Rosch has proposed that our psychological categories contain an internal structure, in that members of a natural category differ with respect to "centrality of membership." A sparrow, for example, would be a more prototypical member of the category 'bird' than would a penguin (which would be a more peripheral member). Thus, for the coastal region, "the thunder of waves in a storm" is likely to obtain high prototypicality ratings, indicating it resides in the essential core of the notion of coastal experience. Importance ratings supplement prototypicality ratings in the derivation of PEQIs: some indicators which are central to the experiences afforded by a type of setting may not be as important for evaluating environmental quality within it. Thus, for forest regions, "the feel of pine needles underfoot" may display high prototypicality ratings but may not function critically in evaluating specific settings.

With regard to Class I lands, I know of no comprehensive analyses of the prototypicality and evaluative importance of the various experiences they afford. Nonetheless, I think we all might anticipate that the clarity of detail in vistas, extensive visual range, and absence of discoloration in the atmosphere would rank high on both criteria and comprise significant PEQ indicators for Class I lands. Thus, I conclude that Congress has probably displayed shrewd insight into our construct of environmental quality for Class I lands.

Nevertheless, to implement Section 169A of the Clean Air Act Amendments of 1977 through recommending methods for identifying and characterizing visibility impairment in Class I areas, further efforts are needed on the conceptual analysis of visibility quality. Our discussion yesterday revealed individual differences among ourselves on what constitutes visibility quality and also highlighted its multiple-attribute character. Extent of view (or visibility range), clarity of detail, and absence of discoloration are components, but examination of Bill Wagner's photoslides indicated that even with visibility range held constant, an array of middleground qualitative variations are associated with manmade emissions. Adjectives such as "hazy," "expansive," "messy," "clear," "distinct," "gucky," and others were employed by us in attempting to characterize varying conditions of visibility quality. Thus, research on what observers mean by visibility quality seems to be in order. In addition, we must identify appropriate perceptual-cognitive judgment procedures for determining observer-based on-site appraisal of visibility quality and impairment. For both of these purposes, our rich descriptive vocabulary for expressing impressions of environmental conditions can be marshalled. The character Edward in Jane Austin's novel, Sense and Sensibility, illustrates this point in commenting (or actually declining to comment) upon what he has seen in a walk through the countryside:

> "You must not inquire too far, Marianne - remember, I have no knowledge in the picturesque, and I shall offend you by my ignorance and want of taste if we come to particulars. I shall call hills steep which ought to be bold; surfaces strange and uncouth, which ought to be irregular and rugged; and distant objects out of sight, which ought only to be indistinct through the soft medium of a hazy atmosphere."

Finally, we must acknowledge that any measurement of visibility quality and impairment will entail continuous variables; yet for policy and management purposes, some definite cutting point establishing what is acceptable under Section 169A and what is not is required. Should this threshold or standard be formed upon a historical basis (i.e., the highest quality of visibility over the period of record), upon a present baseline established by immediate monitoring operations, or upon certain site-specific criteria? And whose judgments should be considered in the process of making these decisions? Research outlining how the general public can participate in each of these steps (i.e., conceptual analysis, on-site observer judgments, and standard setting) will be suggested in my closing recommendations.

B. Monitoring operations.

The use of PEQ indicators generates a set of methodological options including: the selection of instructional sets, the selection of observers, and the selection of media of presentation.

1) Instructional sets.

The perception of settings is in part a function of the cognitive set of the observer. For example, Leff and his associates (Leff, Gordon, & Ferguson 1974; Leff 1978) in their studies of environmental perception ask their research participants to view scenes after being primed to such cognitive sets as: consider the shapes, lines, colors and textures of the scene; imagine how the specific environments might be made more pleasant; and, figure out the values or goals represented by the human influences upon the scene.

For our purposes, perhaps the most important contrast is between a physical cognitive set and an institutionally meaningful cognitive set. Take the case of a California professor jogging through campus. An elderly person from

a backwater town or a visitor from another planet might see the physical properties of the event: a man running through a open space with just his shorts on, but the terms "professor," "jogging," and "campus " interpret the event in the context of social institutions, customs and meanings.[3] Asking observers to evaluate the clarity of vista, range of visibility, or amount of discoloration in an anonymous landscape scene may yield quite different results from judgments of the same attributes for a scene from "Class I lands" or from a "National Park" or "Wilderness area." Furthermore, these results may differ from judgments of the same attributes made after observers have been briefed on Section 169A of the Clean Air Act Amendments of 1977 and the intent of Congress embodied in it.

Thus, the matter of instructional set offers an array of possibly critical options. We need some straightforward empirical research on the effects of certain instructional sets upon judgments of visibility quality and impairment. If observers are shown color photoslides of varying conditions of visibility quality and impairment and asked to make judgments, what is the effect of including the following kinds of information in the instructions to them:

1. information on whether the scene is taken from a Class I area (or even the specific site, e.g., National Park or Wilderness Area);
2. information on the nature and purpose of pertinent sections of the Clean Air Act Amendments of 1977 and acknowledgement that the observer's judgments are being solicited within the context of implementing that legislation;
3. information in the form of marker scenes (Craik, 1972) indicating the estimated range of past and prevailing levels of visibility quality, including maximum and minimum conditions;
4. information on the estimated source of any visibility impairment that may be apparent in the scenes.

Research should be direct d to the effects of these alternatives, but selection of the operational instructional set for on-site observer appraisals that is <u>context-pertinent</u> may rest itself upon proper interpretation of the intent of Congress regarding this legislation.

2) <u>Selection of observers</u>.

The importance of the issue of selection of observers is in part an empirical matter. That is, research is needed in determining the influence of observer characteristics upon these judgments and in gauging the amount of consensus that prevails. Of course, the <u>amount of consensus</u> may interact with the selection of instructional set.

One might also argue that if the conceptual analysis shows that the constructs embodied in the Section 169A indicators entail <u>the direct experience</u> of <u>visibility quality</u> in the specific settings under scrutiny, then characteristics of observers (in terms of demographic, social and personality variables) are less central than the role of observer of Class I lands (Craik, 1970). That is, the proper frame of reference for judgments is neither personal preference nor some estimate of general public opinion, but instead the orientation of the on-site observer of these settings. This role could be at least approximately understood and enacted by individuals who have never visited the setting, of course.

3) <u>Simulations, surrogates and models</u>

Must judgments be made on-site or can photoslide simulations yield comparable findings? This matter is also in part an empirical issue but in view of the subtlety of the visual attributes at issue in Section 169A, the standards for evidence of simulation effectiveness can be expected to be set stringently for this context of use. The same cautions must be expressed about the use of optical and electrical surrogates for on-site observer evaluations (e.g. photographic measurements, and telephometer, transmissiometer and nephelometer measures). Evidence for congruence between on-site observations and surrogate measures is required here also and standards for adequate fit can quite properly be demanding in this kind of application.

The task of implementation presents the challenge of identifying and modeling the manmade physical correlates of the core criteria established by Section 169A: on-site human judgments of clarity in detail of vistas, range of visibility, and absence of discoloration.

This task is somewhat analogous to the current efforts to identify the physical land form and land use correlates of judgments of scenic quality. In that instance, recent achievements are impressive (e.g., Zube, Pitt & Anderson 1975). Nevertheless, in our report on perceiving environmental quality, Zube and I offered these cautionary remarks:

> "..., there is potential hazard in employing physically derived indices prematurely as surrogates for observer-based evaluations. Statistically derived combinations

[3] I owe this example to Stuart Hampshire (Hampshire 1978).

of physical measures are likely to yield substantial but far from perfect predictions of PEQIs. Thus, there is the danger that these imperfect surrogates will become embedded and enshrined in standards and guidelines that abstract only a partial set of components of environmental quality. Their widespread application in the field may systematically and relentlessly eliminate essential elements of environmental quality not captured in the statistical equations" (Craik & Zube 1976, p. 7).

The search for manmade emissions that correlate with observer-based judgments of clarity in detail of vistas, range of visibility and discoloration of the atmosphere in Class I lands is certainly entailed in the implementation of Section 169A; otherwise controls could not be instituted. I would caution against allowing multiple regression equations from these quite imperfect models to replace on-site judgments of observers as the ultimate means of monitoring the on-going overall effectiveness of this program's success in achieving the will of Congress.

IV. Recommendations

In closing, I have three sets of recommendations to offer:

Recommendation I. Bear in mind the full range of purposes served by on-site, context-pertinent field judgments of visibility quality and impairment.

The emphasis in our discussions has been upon predictive impact assessment and permit reviews. However, beyond these project-oriented factors, there are requirements for program-oriented and place-oriented monitoring. First, on-site observer judgments constitute a basis for judging the effectiveness over time of the federal agencies responsible for implementing the legislation. This function is in keeping with the increasing emphasis upon accountability and program evaluation. Second, on-site observer judgments provide a basis for communicating trends in visibility quality and impairment in Class I areas to the general public, elected officials and decision-makers. Even with good intentions and agency effectiveness, nevertheless scientific ignorance, technological limitations, and consideration of economic and other societal factors may result in relative failure to implement the legislation. If so, we should be able to gauge the extent of decline in visibility quality in Class I areas, for purposes of long-range policy or political action.

Recommendation II. Avoid the temptation to abandon on-site context-pertinent field judgments of visibility quality and impairment for the following imperfect substitutes:

1. Instrumentation. Proposed optical and electrical surrogates for on-site observer evaluations may ultimately serve a useful and efficient purpose in monitoring operations. However, the indices they provide may not fully capture our construct of visibility quality and impairment. Research gauging the extent to which they do so is essential.

2. Modeling techniques. Predictions from current models may be the only recourse in impact assessments and permit reviews. However, the amount of variance in on-site observer judgments that models are likely to account for will be sharply constrained by limits to current scientific knowledge and technology; furthermore, validational research on present models is inadequate.

3. Overt and hypothetical behavior. Monitoring what people do rather than what they report they see and experience may readily lead to misleading and invalid indices. For example, attendance at national parks may remain high over a decade of steadily degraded visibility conditions. Yet visitors in the 10th year of the decline, journeying to a national park because it is still among the best available environments, if shown photo-slide records of the highest past levels of visibility quality and the current level, would immediately recognize the magnitude of their loss, and ours. Similarly, hypothetical behaviors such as statements of willingness to pay in bidding games appear to be remote from the implications and intentions of Section 169A and yield notably indirect bases for suggesting cutting points, standards or thresholds of acceptable visibility quality.

4. Psychophysiological measures. Although basic research on the psychophysiological concomitants of scenic quality evaluations is an important item on the agenda for a full scientific account of environmental perception, the immediate relevance of these measures for implementation of Section 169A has not been established. The legislation refers not to phasic alpha levels but to visibility impairment - a condition most validly and directly measured by on-site observer judgments.

Recommendation III. Conduct research that will guide the development of procedures for on-site, context-pertinent field judgments of visibility quality and impairment.

A sequence of research is required.

A. Conceptual analysis and instrument development. A set of appropriate descriptive adjectives can be generated by 1) having panels of judges nominate appropriate terms from existing environmental adjective check lists, and 2) showing panels of judges color photo-slides of varied conditions of visibility quality and impairment and requesting them to nominate 10 descriptive terms per scene. Prototypicality and evaluative importance ratings can then be employed to identify constituent elements of the construct: visibility quality, and yield a Visibility Quality Adjective Check List (VQACL). The use of rating dimensions such as extent of view, clarity of detail, presence of discoloration, and overall air quality will yield a second complementary instrument: Visibility Quality Rating Scales (VQRS).

B. Methodological studies. The measures provided by on-site use of the VQACL and VQRS should be related to indices afforded by telephometric and related instruments. VQACL and VARS results from on-site judgments should be related to VQACL and VARS results from color photo-slide presentations. The measures yielded by the VQACL and VQRS should serve as criteria, or predictive targets, for physical modeling efforts.

C. Studies of instructional set. The effects of instructional set of the sort outlined earlier upon VQACL and VQRS measurements should be studied to guide formulation of a context-pertinent instructional set for on-site visibility monitoring and for research studies. I would suggest that context-pertinent judgments of visibility for these purposes require that observers be informed 1) that the scenes are from Class I areas and what that designation entails; 2) what the Clean Air Act Amendments of 1977 intend, and 3) that their judgments are part of the broad process of implementing that legislation.

D. Establishing cutting points and standards. Using context-pertinent instructional sets, a array of color photo-slides depicting varying ranges of visibility quality and impairment can be displayed to panels of judges, who are asked to indicate the breaking point between conditions that they interpret as acceptable and not acceptable within the framework of the Clean Air Act Amendments of 1977. Panels can be composed of Class I area users, stratified representative samples of the general public, special interest group members, agency staff professionals and others, to establish a basis for gauging the extent of consensus that prevails on this judgment. The resultant cutting point can be compared to thresholds that may emerge from other decision-making processes, including bidding games, agency staff analysis, legal rulings, etc.

E. Long-term place-oriented monitoring. Regular monitoring operations using on-site, context-pertinent judgments of visibility quality will require consideration of systematic site sampling, based upon a reasonable taxonomy of Class I area viewing points. This on-site monitoring will provide a fundamental criterion for appraising the effectiveness of color-photoslide simulations, surrogate instrument monitoring, and the predictive validity of modeling techniques. Long-term trends will also offer a means of gauging agency effectiveness and the degree to which the goals of the Clean Air Act Amendments of 1977 are being attained.

Yesterday, in establishing a contrast with health-related aspects of air pollution, which entail imperceptible components, Frederica Perera noted tellingly that in the case of visibility impairment, "we have observed it with our own eyes." My major recommendation follows directly from that recognition: that on-site, context-pertinent field judgments of visibility quality and impairment form the enduring long-term basis for the implementation and monitoring required by Section 169A of the Clean Air Act Amendments of 1977.

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The Visibility Problem: Economic Assessment Perspectives

This final section contains contributions that emphasize economic assessment strategies for determining how people value visibility. In his paper, Randall describes approaches that could be useful to both psychology and economics thereby suggesting a bridge between this and the previous section. Brookshire adds to the discussion of economic assessment techniques his perception of some of the issues involved in understanding values associated with visibility.

The Economic Value of Atmospheric Visibility[1]

Alan Randall[2]

Abstract.--The value of atmospheric visibility is discussed in a conceptual framework appropriate for benefit/cost analysis. Techniques of value estimation are surveyed, and the relationships among objectively measured aesthetic parameters, subjective aesthetic appeal, and economic value are considered. At several points the usefulness of approaches based on both economics and psychology is highlighted.

Atmospheric pollutants may impair atmospheric visibility by reducing visual range and contrast and causing discoloration. In an unregulated environment, these pollutants are emitted into the atmosphere by individuals and firms, because that is the least-cost waste disposal strategy for those individuals and firms. Thus, reduction in polluting emissions in order to maintain and enhance atmospheric visibility increases the costs faced by individuals and firms, directly through the use of more expensive waste disposal methods, and indirectly through taxes paid for the operation of governmental agencies to establish and enforce emission controls.

Given the maintenance and enhancement of atmospheric visibility is expensive, it makes good sense that it be pursued with some concern for the relationships between costs and benefits. The perspective of economic theory permits us to be more specific: the efficient level of atmospheric visibility is that level at which the incremental costs and incremental benefits of the last added unit of visibility are equal.

Research to identify strategies to satisfy this goal is a very complex undertaking, involving the establishment of relationships between: (1) the cost of emissions control, the level of emissions, the ambient concentration of atmospheric pollutants, and the magnitudes of objectively measured parameters related to visibility; and (2) objectively measured visibility parameters, human perceptions of visual quality, human preferences with respect to visual quality, and economic values of atmospheric visibility. While recognizing that both (1) and (2) are essential for determining the efficient level of atmospheric visibility, and that the issue of appropriate regulatory strategy raises important legal, political, institutional and social concerns beyond economic efficiency, I plan to confine my remarks to the relationships in subset (2).

A. THE ECONOMIC CONCEPT OF VALUE

Where $V°$ is the initial level of visibility however measured) the $Y°$ is the individual's initial income (figure 1), the economic value to the individual of visibility change is depicted by a curve (of positive slope, if increased visibility is preferred) passing through the origin at $Y°V°$ (for a complete development of this concept, see Bradford, 1970). For increments in visibility, eg. V^+, the value to the individual is WTP_{V+}, the maximum amount the individual would be willing to pay in order to enjoy the increment in visibility from $V°$ to V^+. If the individual actually paid WTP_{V+}, thus reducing his budget available for other goods and services by that amount (i.e. his new budget would be $Y° - WTP_{V+}$), and obtained the V^+ level of visibility, he would be exactly as well-off as he was at $Y°V°$. The visibility-loving individual would be worse-off (at $Y°V^-$) if he suffered an uncompensated visibility loss to V^-. He certainly would not be willing to pay any positive amount to obtain the visibility change from $V°$ to V^-. There is, however, some amount

[1]Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

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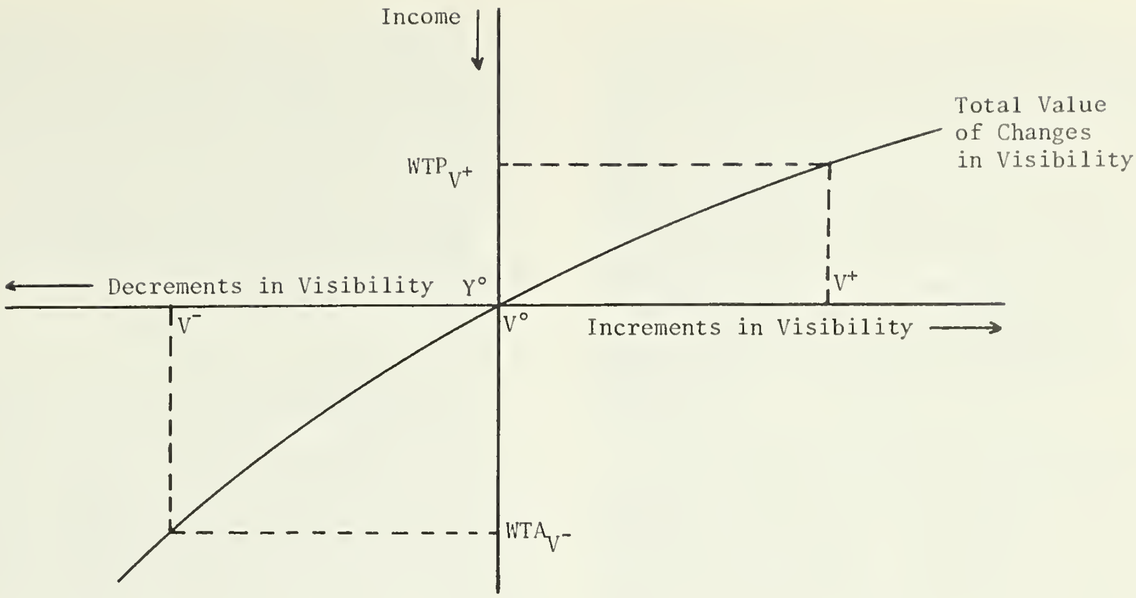

Figure 1.--Total value, to an individual, of changes in visibility where V° is the initial level of visibility.

that he would be willing to be paid, i.e., willing to accept. WTA_{V^-} is the minimum amount he would be willing to accept in order to permit the change from V° to V^-. He would be exactly as well-off at V^- with a budget of Y° + WTA_{V^-}, as he was at Y°V°.

If a market existed in which he could buy the change from V° to V^+ for some amount less than WTP_{V^+}, he would proceed with the purchase and would enjoy a gain from the trade. If a market existed in which he could sell the change from V° to V^- for some amount more than WTA_{V^-}, he would proceed with the sale and enjoy a gain from the trade. If the change to V^+ would cost more than WTP_{V^+}, and the change to V^- would net the seller less than WTA_{V^-}, the individual would conclude that he is best off to simply remain at Y°V°.

That is how markets work, when they work. When markets are vestigial, at best, as they are in the case of atmospheric visibility, there is no reason to assume that the population consists only of individuals each of whom is enjoying his personal economically optimal level of atmospheric visibility.

Assumptions Underlying The Economic Concept of Value

Economics has achieved some precision in the definition of the concept of value (if not in its empirical measurement) by developing a precise, if restrictive, model of individual choice. The individual is assumed to choose rationally among the alternatives available to him. This means:

(i) He knows the range of alternatives available to him and the constraints which limit his feasible range of choice.

(ii) He has preferences. That is, he can rank any pair of alternatives such that A is preferred to B (or vice-versa), A is at least as preferred as B (or vice-versa), or he is indifferent between A and B.

(iii) His preferences are transitive.

(iv) His preferences, along with the constraints facing him, determine his choices.

The assumptions may seem a little strong, to psychologists. Psychologists have less faith in cognitive processes than economists, presumably because they know more about them. Thus, psychologists are less sure that the individual can know the range of choice and rationally array the alternatives. While the economist treats preference as a truly fundamental datum (and one of the very few informational inputs accorded such status), the psychologists are less impressed. Preference is a forward-looking concept, an expectation of future satisfaction, if you will. So, how (the psychologists ask) can the individual know so much about future satisfactions that his preferences can form the basis of value?

Nevertheless, Lea (1978) found considerable correlation between economic and psychological

data. He speculated that the economic demand schedule may be analogous to the psychological reinforcement schedule. This permits considerably more sympathetic communication between the economist and the psychologist. Economic "preferences" can be viewed as reinforcements from experience and other stimuli, rather than the expectations of the clairvoyant, with much more equanimity on the part of the psychologist and little loss by the economist. The economist merely has to accept that experience and other stimuli may change the pattern of "preferences," and thus the relative values of different kinds of goods and services, over time. The argument of Solomon and Corbit (1974), that some motivations (especially those concerning additions) are based on opponent-processes which are substantially physiological and bear little similarity to the economist's concept of rational choice, is of relatively little concern to us here. Solomon and Corbit recognise that there are many kinds of motivations which do not seem to be subject to opponent-processes, and they specifically identify aesthetic experiences as exempt from opponent-process motivations.

At this point, I will take the liberty of concluding that the economic concept of rational choice, although clearly idealized for analytical convenience, has some basis in the psyche of the human species. Returning, momentarily, to the subject matter at hand, if attitudes toward enhanced visibility are positive among many persons, at least a subset of those persons would, if conditions were favorable for such trades, engage in trade to purchase a level of visibility enhancement optimal to themselves given the constraints they face.

Economic analysis must move beyond the concept of individual values, if it is to say something useful about choices in a societal context. Typically, the preferences of individuals are weighted by their budgets, so that the preferences of those with larger budgets count more. This is true in both the purely individualistic form of microeconomic theory and its benefit/cost analysis form.[3] With this weighting, and given a world of existential scarcity (determined by resource availability and production technology), relative valuations of quite disparate goods and services will be determined by patterns of trade. Given a medium of exchange, money, these relative values will be expressed in common monetary units. Fix the supply of money, and absolute prices for different goods will emerge. These prices represent marginal societal valuations of the various goods. In the case of many natural and environmental resources, potential quantity changes are nonmarginal; in these cases, individual valuations of changes (figure 1) are aggregated in order to determine the aggregate values of changes as Hicksian measures of economic surplus (Randall and Stoll, in press).

[3]Some economists attempt to make economics less blatantly oriented toward the <u>status quo</u> by "correcting the bias" with "distributional weights." But, this practice, whether guided by social welfare function logic or merely by the economist's or someone else's whim, has a distasteful element of ad-hocery.

B. MEASUREMENT OF VALUE IN THE NONMARKET INSTITUTIONAL ENVIRONMENT

The problem situation at hand is highly unfavorable to the kind of trades from which individual and aggregate valuations emerge. The quality of ambient air, especially its quality when measured in terms of its usual characteristics, is clearly a collective good. Due to the nature of air and to the long distance in which visibility is measured, there exists no real prospect of directly establishing private, exclusive rights to air, in order to permit the operation of markets in visibility.

When confronted with such situations, the economist who remains determined to estimate the economic value of such goods must choose between two general classes of methods: (1) methods which examine markets in goods which bear some clear relation to the subject good (i.e. the good to be valued) and, through analytical processes of varying degrees of complexity and ingenuity, attempt to infer "shadow prices" for the subject good; and (2) contingent valuation methods, in which hypothetical markets in the subject good are established under experimental or survey conditions and used by people (experimental subjects or survey respondents) to establish values for the subject good.

The inferential methods (group 1 above) require that a number of quite strict and esoteric assumptions be satisfied, in order to ensure validity (Maler, 1974; Rosen, 1974; Muellbauer, 1974; Pollack and Wachter, 1975). But, there is an obvious prior concern: it must be possible to identify a marketed good which bears an appropriate relationship to the subject good. In the case of visibility over class 1 lands, that is not easy. Often-used marketed goods for inferential analysis are the inputs directly used in travel (for valuation of recreation experience via the "travel cost method")[4] and land (for the valuation of air quality in metropolitan areas, beachfront amenities, water quality as it influences residen-

[4]See Cesario and Knetsch (1976), Clawson and Knetsch (1966), Burt and Brewer (1971), Dwyer <u>et al</u>. (1977), and Gum and Martin (1975).

tial amenities, etc.).[5] However, neither of these goods seem to offer especially promising opportunities for inferential valuation of visibility over Class I lands. While such lands are often used for recreation, it is unlikely that the travel cost method is sufficiently precise to permit isolation of the economic value of visibility from among the multitude of variables affecting the desirability of alternative recreation sites. At first glance, the land value methods seem to offer even less hope, since Class I lands are typically in the public domain and not available for trade. However, there are some private lands, in relatively clean air environments not dissimilar to Class I lands, which are available through the market for use as sites for second and vacation homes. It may be possible to use the land value method to estimate that portion of the economic value of atmospheric visibility which would be reflected in the market for such land.

The fact remains, it seems to me, that contingent valuation methods provide far and away the best hope of reasonably accurate estimation of the economic value of atmospheric visibility over class 1 lands. These techniques, since they rely on hypothetical markets, induce some skepticism among those economists who prefer to record the price "after the money has changed hands." On the other hand, psychologists have considerable experience in attitude measurement and the analysis of attitude-behavior relationships. This experience has led them to (1) substantially refine the concepts and practice of measuring such relationships and (2) place more faith than some economists in the results of competent empirical research along these lines. For these reasons, I place considerable emphasis on psychological concepts as a basis for contingent valuation methods, and on psychological evidence to test the validity of the results of contingent valuation exercises.

Contingent valuation methods include (1) those which attempt to directly elicit values from subjects using hypothetical markets, and (2) those which attempt to determine how subjects change their choices when confronted with changes in quantity or quality of the good, and use that information in a sophisticated and complex analytical framework to estimate the value of the good. Examples of the second group of methods can be found in Blank et al (1977), Brookshire, Randall et al (1977) and Thayer and Schulze (1977).

I propose to concentrate upon the first group of techniques. This group includes two types of survey methods: the iterative bidding method which is best adapted to the personal interview mode of data collection (see Randall et al, 1974a and b; Brookshire et al 1976; Blank et al, 1977; Brookshire, Randall et al, 1977; Randall et al, 1978); and a non-iterative "asking" method adaptable to mail surveys (Hammack and Brown, 1974) which, in my opinion is less reliable. In addition it includes a considerable variety of experimental methods, e.g. Bohm (1972), Babb and Scherr (1975), Tideman and Tullock (1976) and Smith (1977); of these, I prefer on conceptual and pragmatic grounds the format developed by Smith.

In my view, the iterative bidding method has several advantages, at the present time: its conceptual logic -- in particular, its relationship to economic theory, in general, and the correct Hicksian compensating measure of benefits and costs -- has been worked out (see Bradford, 1970; Mishan, 1971; Willig, 1976; Randall and Stoll, in press); it has been applied to a wide variety of goods (see reference in previous paragraph); it permits valuation of many individual components of complex amenities (see Brookshire, Randall et al, 1977, who estimated the influence of variations in terrain and game populations on the value of the hunting experience); and it is adaptable to measurement of activity values, option values (Schmalensee, 1972) and existence values (see Brookshire, Randall et al, 1977). The method has one significant problem which has not been entirely resolved: it may be susceptible to strategic influences. Several of the experimental formats may have the potential to eliminate strategic influences. Thus, further development and application of these methods may eventually convince me of their superiority.

Hebert et al (1978) have prepared a working paper in which they submit the iterative bidding method to searching psychological analysis. They find that, when evaluated according to the criteria developed by Ajzen and Fishbein (1977) for successfully using attitude measurement in behavior prediction, the iterative bidding framework stands up rather well. Many caveats remain, and these caveats provide a good basis for refining the iterative bidding framework to eliminate possible sources of bias and subject confusion (which causes unnecessarily high variance in results). Hebert et al offer a particularly interesting discussion of the differences between psychological and economic-legal interpretations of the concept of rights. This discussion leads to recommendations that bidding formats be compatible with people's concepts of "fairness"; if necessary, the raw data can be later manipulated to make it compatible with legal realities and economic concepts of benefits and costs (Randall and Stoll, in press, provide the theoretical basis for these manipulations).

[5] See Brown and Pollakowski (1977), Freeman (1974), Lind (1975), and Smith and Deyak (1975).

C. THE RELATIONSHIP BETWEEN OBJECTIVELY MEASURED VISIBILITY, PERCEIVED VISIBILITY, PREFERENCES WITH RESPECT TO VISIBILITY, AND THE ECONOMIC VALUE OF VISIBILITY

If the above relationships were well defined and subject to expression as a simple mathematical function, the problem of empirical valuation would be immensely simplified. Following objective visibility measurements, the economic benefits from a given increment in visibility could be read from a simple table.

My current opinion is that these relationships are obviously not so simple; on the other hand, they are not completely intractible. Randall et al (1978) showed a clear and consistent relationship between the mean scores of surface mined environments (similar, except for the degree of effort expended in reclamation) on a subjective preference scale and mean WTP for the aesthetic improvements presented by the more completely reclaimed environments. In an on-going study at Battelle Pacific Northwest Laboratories, quite consistent relationships have been shown between objectively measured aesthetic attributes of scenes and people's subjective evaluations of their aesthetic appeal (Adams and Currie, 1978); and between objective scores and WTP, and subjective scores and WTP (Currie et al, 1978). Much more refinement and replication of this kind of work is necessary. However, it provides some hope that objective measurements and/or subjective aesthetic appeal scores will be refined, and will eventually be useful predictors (or, at least, useful inputs in prediction) of the economic benefits of visibility enhancement.

D. CONCLUDING COMMENTS

The economic concept of value, when applied to non-rival and non-exclusive goods such as atmospheric visibility, has certain inherent problems. One of these problems, budget-based weighting of individual preferences in the process of aggregation, is common to all applications of economic valuation. The other major problem, the absence of functioning markets in which observable valuations may emerge, may be substantially overcome by judicious application of the techniques discussed in section B (above).

On the other hand, economic valuation has several advantages as a device through which human preferences can be brought to bear on the decision process. It enables value comparisons, in common terms, across very different kinds of goods, services and amenities. It permits expression of the differing intensity of individual preferences. It permits adjudication of priorities among a population where individual preferences may differ not just in intensity, but also in direction; decisions can be made without the need for unanimous choices or arbitrary voting rules. Finally, it generates values expressed in terms directly commensurable with costs.

Clearly there is much to be done before reliable empirical estimates of the value of atmospheric visibility in Class I lands will be readily available. But, my purpose has been to suggest that more progress has already been made than is perhaps widely realized. An additional purpose has been to suggest that cooperation between economists and psychologists will be useful in several stages of the research process.

In the interim, while we await reliable empirical estimates of the value of atmospheric visibility, a consideration of the economic concepts of value (discussed in section B, above) permits us to raise the level of the debate about atmospheric visibility regulations from the simplistic and misleading "visibility regulations will raise the cost of electricity" to the more realistic and relevant "visibility regulation offers the opportunity to obtain electricity and improved environmental amenities at a higher cost than for electricity alone." This latter statement implies no particular answer, but it does suggest the right question.

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Issues in Valuing Visibility: An Overview[1]

David S. Brookshire[2]

Abstract.--A methodology based on iterative bidding processes is advocated as a strategy for evaluating visibility. An overview of the iterative bidding approach is provided along with specific examples of investigations using this approach. Recommendations are made for integrating the bidding process with overall visibility assessment efforts.

INTRODUCTION[3]

The Clean Air Act of [4]1977, Section 168A, states that "Congress hereby declares as a national goal the prevention of any future and the remedying of any existing impairment of visibility in mandatory Class I federal areas which impairment results from man-made air pollution." Congress, however, did not specify a clearly defined set of procedures for evaluating this goal. As an example, consider the Rocky Mountain Region where approximately 14 million acres have received a federal Class I classification. Much of this land encompasses National Parks such as Bryce and the Grand Canyon which represent national scenic vistas. Most, if not all, of these recreation areas depend in principle on attributes reflected by visual range, scenic vistas and clear colors of the surrounding landscapes for their attractiveness. Figure 1 illustrates the Class I areas in the Rocky Mountain Region. Table 1 indicates the visitation level for some of the areas in Figure 1. The question remains despite classification, what is the value on national vistas for recreation purposes and how does the value compare to the benefits of energy development.

The principal cause of visibility reduction for these Class I areas will be from energy development in southeastern Utah. Visibility effects produced by the Four Corners Power Plant and the San Juan Power Plant have already impaired the visibility in the region. A recent study for the Southwest has documented an average decline in visibility of about 20 miles over the last 20 years (Trijonis and Yuan). The visibility reductions for recreationists from additional power plants in the region will be caused by localized plume effects for a particular national vista (i.e., the Grand Canyon) and also regional effects due to haze and possibly a combination of both

This paper, using the Rocky Mountain Region as a focal point, will examine some of the methodological issues associated with responding to the Clean Air Act of 1977 in valuing national vistas protected by Class I designations. These include questions pertaining to whether economics as a discipline is able to value visibility, linkages to the physical parameters of visibility in a valuation response and some preliminary answers to questions specifically raised in preparation for this workshop from existing work and issues to be addressed if the Rocky Mountain Region were choosen as a research test area.

OVERVIEW OF ECONOMIC METHODS[5]

The motivation for placing a value on environmental goods lies in the goal of employ-

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[1]Paper presented at the Workshop in Visibility Values, Fort Collins, Colorado, January 28 - February 1, 1979.

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[3]This paper draws heavily upon a wealth of source material. Specifically it utilizes concepts developed by the Resource and Environmental Economics Laboratory, University of Wyoming, over the last 3 years.

[4]95th Congress, U.S. House of Representatives, Clean Air Act Amendments of 1977, Report No. 95-564 (August 1977).

[5]This discussion is taken from Brookshire and Randall (1978) where a complete discussion of the surplus measures in relation to rights structure and starting points can be found. Surplus measures and their relationship to Bradford bid curves (Bradford 1970) which have been a focal point in nonmarket valuation is thoroughly discussed. Randall and Stoll (1978) extended the analysis of Willig (1976) to permit its application to the valuation of changes in commodity space.

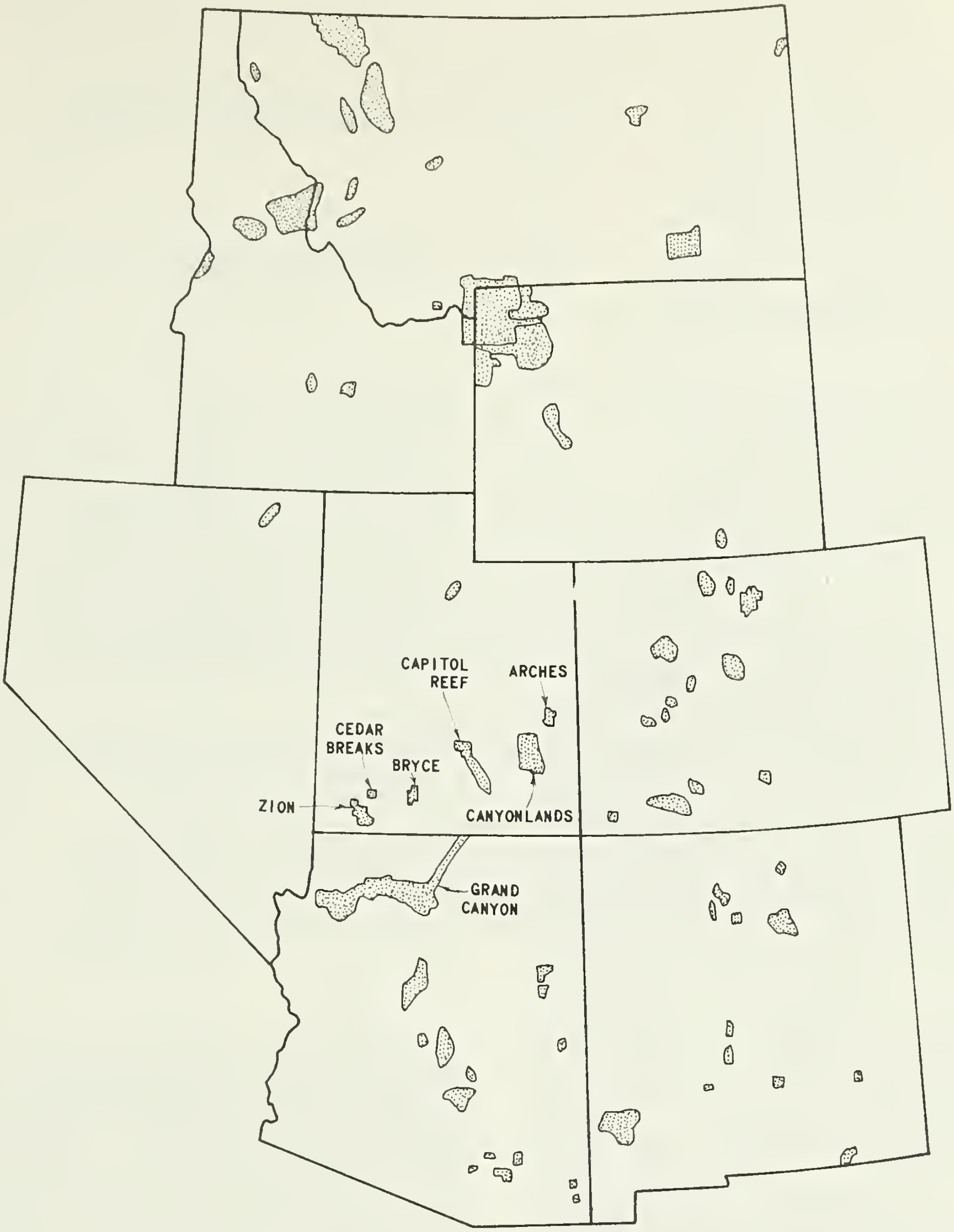

Figure 1.--Class I areas in the Rocky Mountain states.

ing benefit/cost analysis for evaluating alternative proposals. This section will discuss briefly the theoretical underpinnings of non-market valuation and how the price information necessary for benefit/cost analysis can be obtained. Many techniques have been set forth for valuing non-market goods. This section will discuss only the iterative bidding approach.

The iterative bidding technique involves a direct determination of economic values from data which represent responses of individuals to contingencies (i.e., alternative levels of visibility) posited to them via a survey instrument. The individual's problem is then one of responding to proposed contingencies. An example of contingency is plume blight affecting a national vista. Two types of valuation responses can be delineated: willingness to pay (WTP) and willingness to accept compensation (WTA) for alternative levels of visibility. Thus the bid offered by the individual and the subsequent welfare position for the WTP can be represented as:

Table 1.--Visitation at recreation areas in southeastern Utah*

Area	1975 visits (in 1,000's)**	1975 visitor days (in 1,000's)***
Grand Canyon N. P.	2,383.7	450.0
Bryce Canyon N. P.	457.1	86.3
Zion N. P.	1,025.9	193.7
Cedar Breaks N. M.	261.1	49.3
Capitol Reef N. P.	241.1	45.5
Canyonland N. P.	61.8	11.7
Arches N. P.	193.1	36.5

*Most areas are open all year, but lodging and food are available only from early June through Labor Day.

**A "visit" is defined as "the entry of any person, except National Park Service personnel, onto lands or waters administered by the National Park Service." Source: Public Use of the National Park Service, Fiscal Year Report, 1975, National Park Service, U.S. Department of the Interior, October 1975.

***Approximate figures based on aggregate figures for visits and visitor-hours given in the source above. A "visitor-hour" is defined as "the presence of one or more visitors in a park for continuous, intermittent, or simultaneous periods of time aggregating one hour (e.g., one person for one hour, two persons for one-half hour each, etc.)." The total visitor-hours for the entire National Park System in 1975 was 1,037,380,800, while total visits were 228,947,900. From these a rough days/vist was calculated (0.1888). This figure was then used to approximate visitor-days from the visit figures for each area.

$$U(Q,Y - B) = U(Q',Y) \qquad (1)$$

and for the WTA as:

$$U(Q,Y) = U(Q',Y + C) \qquad (2)$$

where U (•) is the individual's utility function representing preference, Q is air quality, Y is income and B or C are bids made or compensation received. Inherent in the consumer surplus measures represented in equations (1) and (2) are the notions of initial position of the consumer (i.e., the current situation) and the individual's rights structures in relation to the environmental good in question (i.e., whether or not the rights of use of the air shed belongs to the individuals or other groups). Depending upon the relationship of the individual's initial endowment as represented by (Y), position (Q) and the rights (either Q' or Q" where Q" is superior visibility relative to Q') a delineation between equivalent and compensating surpluses for WTP and WTA can be set forth. Thus, the Hicksian compensating and equivalent measures are conceptually different in that the reference welfare level is different: the compensating measure is defined as the amount of compensation, paid or received, which would keep the recreationist at his initial welfare level assuming the change takes place (i.e., keeping the individual just as satisfied in the face of a visibility change); the equivalent measure is the amount of compensation, paid or received, which would bring the consumer to his subsequent welfare level in the absence of the change.

The four relevant measures of value are the following where two alternative quantities, Q' and Q", of the public good Q, where Q" is larger (better) and thus preferred:

1. Willingness to pay to avoid Q'
   $WTP^{E}_{Q',Y;\ Q'',Y',\ Q}$

2. Willingness to pay to obtain Q''

$WTP^{C}_{Q',Y;\ Q',Y:\ Q''}$

3. Willingness to accept compensation and take Q'

$WTA^{C}_{Q'',Y;\ Q'',Y;\ Q'}$

4. Willingness to accept compensation and forego an offer of Q''

$WTA^{E}_{Q'',Y;\ Q'Y;\ Q'}$

where the superscript E indicates the equivalent measure, and C indicates the compensating measure; the first subscript specifies the individual's rights in terms of the bundle of goods (Q' or Q'') and his endowment of the numeraire, Y; the second subscript indicates the starting bundle of goods and endowment; and the third subscript indicates his final bundle of goods after he has paid his WTP or accepted his WTA. His final endowment will be Y plus or minus the amount he actually pays or accepts, respectively.

The four measures of value bear the following quantitive relationship, in absolute term values:

$$WTP^{E}_{Q',Y;\ Q'',Y;\ Q''} \doteq WTP^{C}_{Q',Y;\ Q;,Y;Q''} \leq WTA^{C}_{Q'',Y;Q'} = WTA^{E}_{Q'',Y;\ Q',Y;\ Q'} \quad (3)$$

The importance of distinguishing the four alternative measures lies in the variety of policy questions that might arise. Consider the WTA^{C} measure. This represents the case where the individual via federal legislation has the right to the superior vistas and also represents the current situation yet the individual is willing to accept compensation for a deterioration in air quality. If either an alternative rights structure or initial situation exists then another type of valuation measure will be appropriate. The researcher must be careful to obtain the relevant measure for the policy question to be answered. However, it is not clear direct valuation responses can always be obtained via the survey instrument. Thus the relationship between the measures becomes important (Brookshire and Randall, 1978).

Certain key components of the process for obtaining the valuation measure were identified by the Randall, Ives and Eastman (1974 a,b) study. Briefly these are:

(1) The contingency is based on an institutional setting where the alternative levels of visibility are presented in dimensions of quality (i.e. visual range in the case of air quality), extent (i.e. frequency of plume or haze blight) and time (i.e. duration). Typically a set of pictures are employed in substantiating the contingency via depiction of alternative levels of air quality.

(2) Through an iterative bidding procedure employing a vehicle of payment, the respondent is asked whether for a change in visibility he would pay (or accept depending on the situation) \$X. This auction process is continued until the respondent states he would not pay the suggested amount.[6]

A concern for this type of procedure is the credibility. Potential biases with regard to methods purporting to reveal individual preferences are quite well known (Samuelson (1954). In response to bias questions, specific attempts to address biases in the iterative bidding technique have been undertaken (see Brookshire, Ives, and Schulze (1976); Blank, Brookshire, Crocker, d'Arge, Horst, and Rowe (1978); Brookshire and Randall (1978) Brookshire, d'Arge, Schulze, and Thayer (1978)). These combined studies represent an examination of strategic bias, starting point bias, and informational bias. Briefly these biases can be described as follows. The motivation behind strategic bias lies in the individual perceiving himself better off by not paying for the environmental good under question yet enjoying a given level of provision or alternatively the individual attempts due to grossly different preferences to cause the final sample mean bid to be increased thus imposing his preferences on others. Starting point bias relates to the phenomena whereby the beginning bid offered by the interviewer influences the respondents choice of a

[6]For a more complete discussion of the concept of value and the iterative bidding process, see Bradford (1970) and Brookshire and Randall (1978). The literature relating to the iterative bidding process includes Blank et al. (1978), Bohm (1972), Brookshire and Crocker (1978), Brookshire et al. (1976), Randall et al. (1978), Randall et al. (1974a, 1974b), and Thayer and Schulze (1977). Related attempts include Hammock and Brown (1974), and Charbonneau and Hay (1978). The type of environmental goods considered have included visibility, noise, and wildlife.

final bid. Vehicle bias is where the method of payment (i.e., entrance fees, utility bills, tax schemes, etc.) through its inherent characteristics affects the final bid. Generally speaking these types of biases have not occurred in the iterative bidding results to date[7].

ISSUES IN VALUING VISIBILITY

This section will briefly summarize studies to date that have experimented in valuing visibility via the iterative bidding technique. The purpose of this review is to obtain a brief historical perspective on methods development to date and an indication of what people are willing to pay for different levels of visibility.

Additionally, results from one experiment will provide insights to a few of the questions addressed by this workshop regarding the sensitivity of individuals to changing levels of air quality, the physical properties of air pollution which individuals value, and the relevant groups for defining the value of visibility.

The iterative bidding technique in the current form was first developed and applied by Randall et al.,(1974 a,b) in the Four Corners region of the Southwest. Three contingenices were considered: (a) limited visibility reductions and a view of a power plant with limited visible emissions; (b) moderate emissions from the plant, moderate visibility reductions and moderate existence of unreclaimed soil bank and transmission lines; (c) and finally extensive emissions, visibility reductions and unclaimed soil bank and transmission lines. Given this selection of scenaries, the results cannot be disaggregated into component values for visibility, power plant location, and unclaimed soil banks and transmission lines. Employing a sales tax vehicle, the yearly mean bids were \$85 (a to c) and \$50 (b to c) per household. No bias tests were conducted in this experiment.

The Lake Powell experiment, Brookshire et al.,(1976), addressed the potential visibility reduction from the proposed Kaiparowits power plant which would have impaired the scenic vistas of the Glenn Canyon National Recreation Area. An estimate using the iterative bidding technique was obtained for the aggregate willingness to pay to prevent construction of the proposed Kaiparowits power plant. One of the principle motivations for the study in addition to the Kaiparowits power plant issue was an attempted replication of a subset of the Randall study results. Three scenarios depicted by verbal description and picture sets were employed in the Lake Powell experiment where visibility and plant siting varied from best (a) to worst (c). The study tested for strategic bias in the bidding procedure and concluded that the bias was not prevalent in this experiment. Using entrance fees as a vehicle, the aggregate marginal willingness to prevent one additional power plant near Lake Powell was over \$700,000. Employing the bids and considering all the assumptions and structure of the experiment, an indication of worth via the preferences expressed in the study of the canyon lands of southeastern Utah can be obtained. Extrapolating to recreation areas within a hundred mile radius, the aggregate bid for a similar visibility reduction would be up to \$20 million per year.[8]

The Farmington experiment, Blank, et al., (1978) attempted to value visibility in the Four Corners Region of the Southwest. The study had three principal goals which represented extensions of the previous experiment (1) to attempt to link between visible range and the valuation measures, (2) to develop a theoretical cross check for the iterative bidding process, and (3) to systematically test for a vehicle, starting point and information bias in the iterative bidding process. Starting point and vehicle bias in varying degrees were detected in the results. Later studies including Thayer and Schulze (1977), Brookshire and Randall (1978) and Brookshire et al. (1978) tested for various biases and did not discover them. Various reasons have been suggested as to why the Farmington experiment alone encountered multiple biases. One possibility is the definition of the "good" being valued was poorly specified.

Before addressing the most recent experiment, let us consider the Four Corners experiment, Lake Powell experiment and the Farmington experiment in terms of a comparison of valuation results.[9] As stated the Four Corners experiment reported yearly mean bids of \$85 (a to c) and \$50 (b to c) per house-

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[7]For a specific discussion of the bias results, see Schulze and d'Arge (1977) and Brookshire and Randall (1978).

[8]This clearly assumes at a minimum all sites are identical and preferences for all recreationists across all sites are identical.

[9]The comparison is limited to equivalent variation bids and subsample data sets from each study. No independently conducted experiment this is an exact replication of a previous experiment has been undertaken to the best of our knowledge. A complete discussion of iterative bidding results can be found in Schulze and d'Arge (1977).

hold. The yearly bids for the most comparable situations in the Farmington experiment were $82.20 and $57.00. Considering inflation adjustments for the Four Corners bids and recalling the bids were for soil banks and transmission lines as well as visibility considerations then the subset of results are reasonably comparable.

The aggregate mean bid for the best (a) to worse (c) situation in the Lake Powell experiment was $2.77 per month. Adjusting for inflation of 6.6%, the comparison values are $2.95 for the Lake Powell experiment to $4.56 with the Farmington experiment utilizing a comparable subsample of recreationst. Thus the results of the three experiments have tended toward exhibiting replication.

The Southcoast Air Basin (SAB) experiment[10] was the first urban test of the iterative bidding technique. The (SAB) experiment addressed several new questions in the experimental process. First, information necessary for a cross-check was collected simultaneously with iterative bidding information, not in separate questionnaires as in the Farmington experiment. Second a set of sample areas were choosen within the (SAB) where within any single pair the socioeconomic information according to Census Bureau publications was consistent yet air quality varied. This allowed in analyzing the data to control for many variables formerly requiring statistical treatment. Third, the "good" air quality in the (SAB) study was defined to respondents in terms of characteristic parts. That is, an aesthetic component was bid upon as well as acute and chronic health effects from air pollution. This was in response to questions regarding the Farmington Experiment where the aesthetic valuation measures potentially were confounded by health effect considerations due to emissions of the power plant. Finally, a methodological cross check with the bidding results was conducted using a micro level property value data set drawn for the same sample pairs where the interviewing occurred.[11]

The results of the study did not suffer from vehicle starting point information or strategic bias. The aggregate average dollar bid per household per month was $29 for a 60% improvement in air quality. Further, the independently conducted property value study produced the same order of magnitude valuation results as the iterative bidding portion.

The above extremely brief review of the iterative bidding process experiments to date given an indication of the progress in iterative bidding process in valuing visibility with respect to methods application, replications, bias results, cross checks, and the level of individuals valuation of alternative levels of air quality in different areas. Turning to some of the results of the (SAB) experiment we will attempt to suggest answers to a few questions raised at this workshop.

A continuing issue in valuing visibility is whether the public is sensitive to decreasing levels of air quality. Ideally this question would be addressed with an attitudinal study that would be linked to valuation measures. However, an insight into this issue can be obtained from the (SAB) experiment. A set of questions were administered that attempted to determine whether the respondent has perceived air quality to become worse, stayed about the same or improved during their residence. This information coupled with length of residence in the region suggests a preliminary answer to the above question. No definitive conclusion, however, can be drawn from the results. At a preliminary level, the longer individuals have been a resident then they have perceived as a group a greater deterioration relative to those residing only a shorter period of time.

A second question raised at this workshop relates to which physical properties of pollutants serve as significant clues or prompts to individual perception. The (SAB) experiment was designed in part to address this question by partitioning the "good" visibility into an aesthetic effect, acute and chronic health effects. Utilizing the aggregate bids for all sample areas, 22-55% of the total aggregate bid was for aesthetic effects. This result suggests that indeed the aesthetic component of visibility is a major component of visibility valuation. Further, this result is for an urban area where the preliminary reason for residence is not vistas as would be the case upon a visit say to the Grand Canyon. Thus one might infer that aesthetics, not health effects, would be the principal consideration for scenic national vistas.

Finally, in valuing visibility, especially in recreation areas where no large resident population exists, a question as to what groups should be given attention regarding their perception of air quality in Class I areas arises. We can offer no empirical evidence from the (SAB) study. However, there are three categories of economic value that can be attached to

[10] See Brookshire et al. (1978).

[11] Almost all previous property value studies employed aggregate data at the census tract level. The data employed was by household within census tracts within the sample pairs. This portion of the (SAB) study was conducted by Mark Thayer and William Schulze.

air resources which delineate different groups of individuals. These are activity values, option values and existence values. Clearly this approach side steps issues relating to interpersonal comparisons. Activity values are identified as the value which individuals attach to various direct uses they may make of a resource where visibility is an important component of the overall experience. Option value can be defined as the amount an individual would be willing to pay to preserve the option to consume some good in the future. An example might be a potential future visit to the Grand Canyon to enjoy the vistas which remain unimpaired. Thus option value is a measure of the value attached to keeping the option to engage in some future use of a resource that will generate an activity value. The key element then is uncertainty in the future supply to an individual of the good under consideration. Given the proposed power plants in southeastern Utah, the future supply of pristine visibility can be considered to be in doubt. Finally, individuals may simply value the existence of pristine air quality in recreation areas. That is, existence value is the willingness to pay just to know that such areas exist and will continue to exist yet no future use is anticipated.

The justification for these distinctions in economic values for visibility is that only activity values have been addressed to date. Option and existence values, however, might represent a sizeable dollar amount. Empirical procedures for obtaining option and existence values are under development.[12] Whether the application is workable in the context of visibility is unknown but could be the subject of future research.

The above brief review of the existing work was an attempt to offer some perspective on the current state of art. This section has attempted to suggest answers to a few of the questions raised relating to valuing visibility in response to the needs of the Clean Air Act of 1977. However, it should be quite clear not all the questions have been answered. The next section is an attempt to suggest some lines of future research, again focusing on the Rocky Mountain Region.

ECONOMIC METHODS AND VISIBILITY: RECOMMENDATIONS FOR FUTURE WORK

The second part of this paper provided a brief outline of methodology that could be employed in addressing the value of visibility for the Clean Air Act of 1977. However, several issues remain unresolved by the methodology. First, how is visibility to be precisely defined to a respondent so as to explicitly link the economic values with the physical parameters of visibility. This is critically important when evaluating the trade-off in the Rocky Mountain region between energy development and preserving pristine conditions in the proximity of recreation areas. Second, the question of regional versus localized valuation becomes important when discussing the air quality of the Rocky Mountain region. A band of power plants potentially would produce plume, haze and combined plume and haze effects. A regional valuation is complicated in that individuals might well visit more than one recreation site with different visibility attributes.

Consider initially the relationship between individual perception and reality. In the iterative bidding process, a four way relationship exists in obtaining valuation measures. This includes the existing environmental situation, the potential environmental situation as depicted in pictures, linking the picture sets to physical parameters and finally the individuals perception of that situation.

To date only one attempt has been made to link the physical parameters with the future sets and thus the valuation measures. This was in the Blank _et al_. (1978) study for the Electric Power Research Institute. The principal shortcoming of this attempt was the lack of the use of an air diffusion model linking emissions to regional effects via picture sets to valuation measures. A related issue involves the frequency of occurrence of a particular level of visibility on a regional basis. That is, not only must a picture be tied to physical parameters but the respondent must fully understand the duration and relative frequency of occurring of the particular level of visibility depicted. Iterative bidding processes to date have simply ignored this dimension.

Recent advances in image processing and and computer modeling of visibility effects of air pollution now allow a much more sophisticated, realistic, and precise set of photographic images to be used in the surveying procedure. These advances will overcome the principle problems discussed above.

A 35 mm single lens reflex camera in conjunction with a multiwavelength contrast telephotometer could be used to obtain reference pictures of good visibility for national vistas. Each initial or reference photograph could be then quantified by digitalizing it into 262,000 small pieces. The optimal density of each piece is measured by a microden-

[12] See Brookshire and Randall (1978) for an attempt at obtaining these values for wildlife.

sitometer in each of three primary colors. The digitalized picture would be modified by computer models in order to produce a picture of plume blight, a picture of uniformly reduced visual range, and a picture combining both phenomena. The result would be a set of four pictures for each of the vistas under consideration. Examples of this image processing technique are available which show the simulated effects of a power plant plume and haze in the Canyonlands National Park.[13]

Let us now consider the question of a regional estimate. Most studies of the demand for recreation and associated attributes (i.e. visibility) of recreation sites either attempt to estimate the demand for a single site without considering other sites, or all sites visited by the sample population are combined, and a single expression is then estimated. The latter approach is a "participation study" and is incapable of yielding any information about the consumer's compensated demand function. The former approach suffers from what is sometimes called the "price-dominance" effect; that is, demand is allocated among a new site and existing alternative sites according to price dominance. In case (1), for the former approach, the volume of recreation is unchanged from that existing prior to the introduction of the new site. Moreover, this volume continues to be concentrated exclusively at the old sites. For the residents of region i, there is thus no economic gain accruing from the alternative site. For case (2), in contrast, everybody flees the old sites and flocks to the new site. The economic gain from the introduction of a new site is said to consist of the change in expenditures plus the change in consumer's surplus due to the change in prices from p_i' to p_i'', where p_i' is the cost to residents of region i of visiting the old sites, and p_i'' is the cost of visiting a new site.

For the above analysis to be justified analytically, at least one of the following conditions must be met. First, the new site and the old sites must offer completely identical bundles of attributes, but their prices must differ; or second, if the bundles of attributes among sites are dissimilar, then participants must make their site choices on no basis other than price. These are exceedingly strong conditions. One can remove them by estimating simultaneously a system of demand expressions for a set of competing sites considered to be the universe of recreational sites used by the sample population from region i. Substitutions among sites can then be explicitly taken into account.

The basic objectives would be to model the demand for a set of alternative recreation sites in the Rocky Mountain Region for which visibility attributes are perceived to be important. This would be done so as to: (1) allow for the possibility of intersite substitution; (2) make explicit the relationship between site attributes, including air quality attributes and intersite demands; and (3) permit the explicit calculation of consumer's surplus measures of the benefits of visibility from changes in site costs or air quality attributes. Fulfillment of these objectives requires the simultaneous estimation of the demand for a network of competing recreation sites.[14]

Why are these considerations important in valuing visibility in the Rocky Mountain region. To understand, we must return to the discussion earlier in this section relating to the four cornered relationship between individual perception and reality. Recall that given the modeling technique currently available for linking picture sets to physical parameters, there is no reason to expect a uniform level of visibility in a region to result from various energy scenarios. Coupling this expectation with the concept of preferences, a simultaneous estimation procedure will allow for intersite substitution whereby the relationship between site attributes and air quality attributes will be explicit. This will then allow the calculation of the benefits of visibility levels by site and consider each set of site attributes explicitly.

In sum, future research attempting to value visibility should have at least two key elements:

(1) Specific linkages employing air diffusion modeling techniques and computer picture modification techniques should be linked directly to an iterative bidding technique employing picture sets for valuation purposes and,

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[13] These images can be found in "Visibility and Energy Development: Large vs. Small," by Ellen Leonard, Michael D. Williams, and Mona J. Wecksugn, paper presented at the Air Pollution Control Association Meeting, Houston, Texas (1978). This section was the result of a phone conversation with Dr. Eric Walther, Director of the Visibility Research Center, University of Nevada, Las Vegas.

[14] To the best of our knowledge, there are only two studies of recreation demand that attempt the aforementioned simultaneous estimation. The two studies, Burt and Brewer (1971) and Cicchetti et al. (1976) are, in fact, virtually identical and differ only in the estimation techniques they employ.

(2) A generalized site substitution approach should be employed in order to properly represent the diversity of site attributes in the Rocky Mountain region.

SUMMARY

This paper has tried to briefly address a few of the methodological questions regarding the value of visibiliyt. Hopefully the reader has grasped the essential points that the iterative bidding process has withstood some systematic scrutiny and yet improvements in the overall research design deserve to be tackled.

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Visibility Values: Workshop Discussions

Two working sessions were held following formal presentations by participants. The first session included a request for what information participants could furnish land managers faced with making a decision about a potential source of pollution when they are constrained by a sixty day review period. Workshop participants found the short time period a severe constraint given the current level of knowledge about visibility values. The second work session was focused on having participants suggest a research program without concern for administrative time constraints.

Participant Discussion of Land Managers' Immediate Information Needs About the Visibility Values Issue

A general discussion session was held following the presentation of the formal papers. In this session Fox charged the group to consider the decision which must be made by the land manager responsible for a Class I area. In view of the workshop objective to identify procedures to establish values of visibility, he suggested that a wide variety of methodologies had been aired and it was now time to focus on which approaches are most appropriate. There was some discussion at this point on whether the question of valuing visibility was a relevant one. Indeed, will the land manager's decision reflect considerations of visibility's value, or will it be dictated by other considerations?

At any rate, Fox pointed out, the federal land manager's (FLM) time frame for deciding on a prevention of significant deterioration (PSD) permit is very short, on the order of 60 days from the time the permit is first submitted. He asked if any of the methods presented could be adopted to provide site specific information in that type of time frame. Peterson requested a clarification of the term "values of visibility." Does that mean status of visibility, magnitude of visibility, components of visibility, or costs and benefits of visibility, or all of the above? This question led to the suggestion that a few "givens" exist with regard to the visibility issue, while some other components are open for discussion.

Visibility reduction is caused by particles about the same size as the wave lengths of visible light which scatter, and to a lesser extent, gases such as nitrogen oxides, which absorb light. The particles are mostly generated in the atmosphere as a result of man-made emissions somewhere upwind of the affected location. An array of tools exists which allow prediction of pollutant dispersion and chemical reactions so that an estimate of the amount of material loaded into the atmosphere as a result of a potential facility can be made. It is further possible to evaluate the resulting reduction in visibility associated with this potential facility. Although these tools are complex, often not validated, and quite expensive to apply, they generally will be exercised by a proposed facility to predict the visibility impact. This exercise is often reported to the proposed facility and by them in turn to the EPA, the state, and the FLM, in the form of 200-500 page multivolume reports. The question becomes, what happens from this point on? One concern is simply does the area in question require visibility protection? In 44 FR 8909, the February 12, 1979 issue of the Federal Register, the EPA promulgated a list of mandatory Class I federal areas where visibility is an important value. This list was academic since EPA simply accepted the list provided by the Secretary of Interior (43 FR 7720, Feb. 24, 1978). Of 158 mandatory Class I federal areas, 156 were identified as possessing visibility as an important value. Thus except for Bradwell Bay, Fla., and Rainbow Lake, Wis., all areas require visibility protection.

Some discussion followed relative to what level of decreased visibility is significant. The environmentalists contend that since the Act says "any" visibility reduction, even the slightest detectable decrease in, say, visual range should be disallowed. Others, however, claim that the detectability limit should be measured by human response. Craik pointed out that one can set standards at any of four levels ranging from (1) measurement of what is in the air, (2) a display of the effect of such concentration, (3) a perception scale based upon what can be seen, and (4) based upon values set on the perception scale. The basic question then becomes does one set a standard on the perception scale or on the value scale?

The criteria might well be a political one, it was pointed out by Peterson, namely based upon a level that would elicit an effective political response (i.e., the level at which something will happen).

Fox again suggested that whatever the criteria, the FLM would have to make a decision. He/she would have a lot of information with regard to the amount of pollution and even the degree of visibility reduction, but the essential decision would be to determine if visibility values of the Class I area would be impacted.

Peterson asked why this was any different from the conventional EIS (Environmental Impact Statement) process wherein the states of the environment that will result from a proposed project are described. That description is exposed to the public--anyone who may have an

interest in the problem. Then through due process they raise issues and concerns. The EIS is finalized by identifying those consequences which are not acceptable as determined by public response. Are we trying to do something instead of this public response?

This comment was readily accepted, however, the question of time was raised. Is there sufficient time from the initiation of the permit process or from when the FLM learns about the project to allow for effective public response?

The discussion bogged down here on questions of the legality of a FLM decision, the monies available to make such a decision, etc.

Peterson suggested that a manager could, if insufficient time were available to do otherwise, assemble a sort of Delphi group of proponents and opponents and observe their interaction and base his decision accordingly.

Randall suggested there is tremendous social utility and value in procrastination. Young agencies in particular suffer from not having their procrastination mechanisms in gear. Procrastination is the only thing that keeps options open.

Latimer reiterated by way of conclusion that his figure 2 (see Latimer, this conference) represents a format for discussion of visibility and its degradation in terms of how many days per year at which vistas.

Rudolph suggested that the concept of "how many days" of acceptable visibility reduction was a very hotly contested and debated concept--perhaps the most debated issue in the Clean Air Act, and it was strongly rejected by the Senate.

There were no summarizing concepts from the discussion. Clearly, the experts were unable to suggest any particular approach short of displaying the potential impacts to the public and responding to their desires. Clearly, the visibility section of the Clean Air Act will remain a subject of substantial debate between all the players for some time. It became clear, however, that in order for the FLM to discharge his responsibilities he will have to at least consider developing some of the valuation or value clarification work discussed by the formal presentation. Further, since this work cannot be done in a 60-day time frame, he/she ought to consider starting as soon as possible.

In conclusion, the exercise of holding the workshop participants to a limited time frame demonstrated the critical need for systematic research on visibility values to provide managers with usable information. Some of the practical considerations researchers should keep in mind include:

There is a definite need for a magnitude value reporting system that combines both physical and social-psychological estimates. Managers need a monitoring system that translates physical air quality indicators into estimates of perceived air quality.

. Managers could benefit from opinion poll indicators which would provide insights into current attitudes on significant environmental issues related to management questions.

. Decision makers also need a series of "best guess" or troubleshooting opinions about probable reactions by the public to different conditions of impaired visibility.

Participant Recommendations for Long Range Research Needs

During the final session of the workshop, participants were organized into two work groups which independently discussed long range research needs in the visibility values area. Group One consisted of participants Bhaidwaja, Henry, Perera, Ulrich, with Peterson as Chairman and Sanchez acting as recorder. Group Two had Craik as its chairman, Hilst, Latimer, Leiker and Rudolph as members with Yarborough serving as the recorder. Each group presented a summary of its deliberations and short periods of discussion by workshop participants followed the presentations.

SUMMARY OF GROUP PRESENTATIONS

Group One. The first group presented a three component model which emphasized Physical, Psychophysical and Values research needs. Figure 1 provides a summary of Group One's conceptual model. This model is adapted and reduced from the figure in Peterson's paper in these proceedings.

In the case of the Physical component, the group felt that the needed technology is nearing development and assessments can be

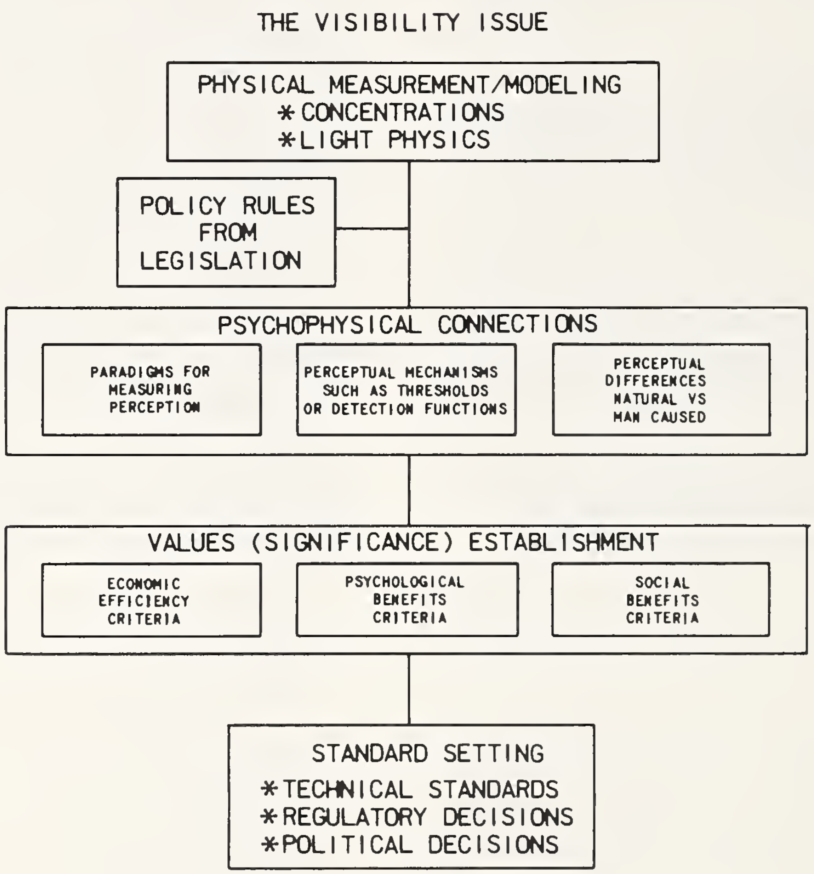

Figure 1.--Overview of recommended areas of research including physical measurement, psychophysical connections, and establishment of value significance.

made. There is a need to (a) define existing models integrating dispersion, optics, and photochemical data (EPA is doing a little of this already), (b) automate for continuous monitoring, and (c) establish baseline conditions.

Consideration of the psychophysical or mechanics of perception component resulted in a general recommendation for a large, well designed study measuring the responses of an extensive sample of individuals to various visibility experiences. A cataloging of responses and identification of responses to visibility values would culminate in the construction of a model of predictive responses.

In terms of value component, although the group contained no economists, members recognized that this field may provide some way of assigning values to air quality. Another tactic would be to investigate psychological and health benefits along with aesthetics. The group suggested that handling value assessments of visibility as well as physiological responses simultaneously should be especially cost effective.

Group Two. The following seven areas of needed research were suggested by participants Daniel and Latimer and adopted by the members of Group Two:

1. Define visibility impairment.
2. Measure impairment.
3. Distinguish human caused from "natural" pollution.
4. Link specific sources with visibility impairment in a target area.
5. Model the source of view impairment.
6. Develop acceptability criteria.
7. Evaluate the validity and effectiveness of research.

Individual members of Group Two discussed ways to develop research strategies that would include public involvement. For instance, Latimer and Daniel plan to look at different groups (such as environmentalists) in different parts of the country by using a book with colored photos with visibility impairment and have visitors rank the photos.

Yarborough, Leiker and Craik extended this strategy for U.S. Park Service application. Perhaps visitors could look at slides of vistas and rate them on an objective checklist (which could be partially developed on college students). Another tactic would be to have visitors rate the extent of visibility impairment, loss of detail, etc. Alternately, one might want to brief visitors on Section 169A of the Clean Air Act, and then have them rate the pictures. A problem with this approach which was identified involves determining how a public sample should be selected. The group also noted the importance of a technical detail of using stable film stimuli in representations of colors in order to standardize the photos. Craik suggested that one might use a geomorphological taxonomic system, i.e., a classification system based on geographic land forms, to "standarize" vistas in the photos. This would allow experimenters to concentrate on those vistas which are most important to people.

Hilst pointed out that visibility must eventually be labeled in terms of human perceptions and these must be related precisely to what equipment designed to monitor physical air properties may or may not be measuring. In the end, as Latimer stated, we are seeking a measurable physical parameter (x) which will correlate highly with judgments of visual quality (see figure 2). It is important that this parameter x must also be relatable to human caused emissions of pollutants.

Rudolph envisioned the act as demanding both retrofitting Best Available Control Retrofit Technology (BACT) on existing major emitting facility (MEF's) and requiring on all new sources (MEF). To identify these sources, however, Latimer points out that we are seeking a visual means to document what aerosols are in the line of sight and their trajectory. Craik mentioned that some efforts to distinguish between human-caused and natural visibility impairment materials is underway. This involves analysis of trace elements which give the "signature" of pollution sources. Latimer suggested that modeling efforts are necessary to determine the trajectory of aerosols, to "fine tune" and validate current models of pollutant transport, and to allow transference of control strategies and equipment to other areas.

Craik noted that discussions of monitoring have generally been from Prevention of Significant Deterioration (PSD) permit application, but now there is also a need to monitor the general state of affairs to create a baseline for accountability and to determine general trends in air quality. Hilst and his associates are working on an automated multivariable telephotometer which will view an entire target scene (both vertically and horizontally) for display on a T.V. screen.

According to Craik, we must move beyond rank ordering of visibility decrements, and work toward threshold standards for section 169A of the Clean Air Act. Hilst stressed that any research must involve a wide data base, not just physical measurements (such as contrast), but people's perceptions as well. Hilst also suggested that the threshold might be determined by comparing the number of people who want further improvements with the cost of achieving such improvements in visibility.

Randall felt that Hilst's suggestion was really a type of cost/benefit analysis. Such analysis could be valuable in determining acceptable criteria for improvement. Specifically cost/benefit might aid in legitimitizing policy with regard to costs and estimating the importance of benefits based upon people's willingness to accept improvement.

In addition the specific content of different scenes could be related to scenic judgment variables to obtain a prediction equation for willingness to pay. Bidding games might be used for both users and non-users of parks. Experiments such as these would help define the cultural opinion of what is a reasonable fee to pay for visibility improvement, and also determine an economic threshold.

GENERAL DISCUSSION SUMMARY

Participants reacted to each group's presentation and provided the following comments:

. Physical modeling of air visibility parameters is an important link that should be related to any consideration of social or behavioral research.

. A standard based on perceived change in the air quality must take into account adaptation responses that require increasingly greater increments of change to be perceived.

. It is important to sample the general public who will pay for any standards, as well as those who actually use Class I areas.

. Measures of social values could be closely coordinated with psychophysical ones. Furthermore, existing studies of recreationist values and preferences could serve as an important resource in visibility research.

. Psychophysiological measures, as well as measures of arousal or visitor excitement, could be used to validate results from other research strategies.

Selected Bibliography on Visibility Values

The following is a collection of several hundred references assembled in conjunction with the Visibility Values Workshop. Included are publications from such diverse orientations as geography, economics, psychology, engineering, and recreation. The emphasis of this bibliography, however, is upon contributions from the behavioral rather than the physical sciences.

During our efforts we discovered a great deal of information related to visibility in general, yet relatively little specifically dealing with the importance of visibility impairment. In some cases we have included tangential literature. For instance, we have included several discussions of landscape assessment in general.

We have no doubt that we may have overlooked several valuable sources. Given the difficulties involved in this interdisciplinary topic, however, we think these citations provide a useful background for further investigations.

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